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LETTER OF TRANSMITTAL

A. B. Parsons, Secretary,
American Institute of Mining and Metallurgical Engineers
29 West 39th Street
New York, N. Y.

Dear Sir:

I take pleasure in transmitting herewith Transactions, Petroleum Development and Technology, 1934, containing papers that cover subjects of general interest to the industry and of especial interest to engineers. Nearly all of these papers were presented at the several meetings of the Petroleum Division held during the past year.

In recent years papers on stabilization have constituted a considerable part of the annual volume, but this subject is treated only briefly in the present volume. The Stabilization Committee has been as active as in past years, and held a highly successful session at the New York meeting; but the resulting papers were thought to be of such timely interest that they were made available immediately to the industry and the public through the technical journals.

The statistical information covering production is presented in a new and far more comprehensive form. For years there has been need of greater detail and refinement in handling production figures. Engineers in particular often need consolidated figures which heretofore they have been unable to assemble individually. This more elaborate treatment of statistical information represents an effort to render a permanent service to the industry, which it is hoped will be of greater value each year.

I wish to express my sincere appreciation to the officers of the Division, the committeemen, the officers and headquarters staff of the Institute, who throughout the year have rendered valuable assistance and advice to further the interests of the Petroleum Division.

Respectfully submitted,
W. E. Wrather, *Chairman,*
Petroleum Division, 1933.

PLANS FOR PETROLEUM DIVISION IN 1934

By H. D. Wilde, Jr., Chairman of Division

The plans for the activities of the Petroleum Division for the coming year do not differ materially from those of the past several years. The fall meeting is scheduled for Oct. 12 and 13 and is to be held at Tulsa, Oklahoma. The Division, of course, will take part in the annual meeting of the Institute at New York. A fall meeting will also be held in California at approximately the same time as the meeting at Tulsa. A number of papers are to be presented at the two meetings simultaneously. The various committees are at work arranging the programs.

The Division will continue to be active in its various fields of endeavor, such as stabilization, production reviews, and economics, but special stress is to be laid on the engineering and research fields. In the past the Division has served as a forum for open and frank discussion of problems confronting the engineers in the oil industry. It is hoped that it will continue to function in this capacity. Papers presenting original ideas and extending the boundaries of knowledge and understanding in the field of petroleum production will be welcomed. Members who have interesting information to contribute should not wait until called upon by one of the Committees, but should offer a paper at the earliest opportunity.

The past year has seen a decided strengthening of the control over production, with prospects of even more rigid control in the future. It is essential that production programs under such control be carefully planned and it is highly desirable that petroleum engineers take an active part in the planning, to insure efficient production of oil and minimize the waste of this natural resource.

At a time like this, when it is difficult to keep the production of oil within reasonable limits, it may seem unnecessary to improve the efficiency of production methods, but, as has been aptly said, the trouble is not that we have too great a reserve of oil but that we are producing tomorrow's oil today. Therefore it behooves those who are entrusted with the engineering and scientific phases of production to learn how to get the greatest yield economically possible from the present and future fields in order that we may enjoy the advantages of petroleum products for a long time to come.

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Chapter I. Production Engineering and Engineering Research

Properties of Hydrocarbon Mixtures as Related to Production Problems

By W. K. Lewis,* Cambridge, Mass.

(Dallas Meeting, October, 1934)

During the last decade the petroleum refinery engineer has made great progress in achieving a better understanding of the physical behavior of hydrocarbon mixtures, with particular reference to their pressure-temperature-volume relationships, the mechanism of the evaporation of liquids, the condensation of vapors, including the changes in composition, and the heat effects accompanying them. With the new insight into the mechanism of movement of oil and gas through the formations in which they occur, achieved by the production engineer, it is clear that the latter will need to utilize in the solution of his own problems much of the information outlined above. It is the purpose of this paper to outline the portions of that information that seem most certain to prove of importance in production work.

Properties of Pure Hydrocarbons

While it is true that petroleum always consists of highly complex mixtures of hydrocarbons, none the less understanding of the behavior of the mixture must be based upon a knowledge of the properties of the pure components. However, in view of the tremendous number of hydrocarbons existing in petroleum, the determination and formulation of the properties of all of them would seem a discouraging task. The difficulty of the situation is increased by the undoubted facts that the overwhelming majority of chemical individuals in petroleum have never been isolated as pure compounds, none of their physical properties have been determined and even their chemical constitution is unknown. The situation would be hopeless were it not for the fact that certain extraordinary correlations of important properties of various hydrocarbons have been discovered which make it possible to predict those properties for a given chemical individual on the basis of a very limited characterization of it. Thus one can predict the vapor-pressure curve of an unknown hydrocarbon over a considerable range from the knowledge of a

* Professor of Chemical Engineering, Massachusetts Institute of Technology.

single point on that curve, with no other information whatsoever as to the nature of the hydrocarbon; if, in addition to this one point, one knows the molecular weight and the density of the hydrocarbon, one can estimate the whole vapor-pressure curve with reasonable precision from these three bits of information and nothing else. Indeed, it is not impossible that a knowledge of three characteristics of an unknown hydrocarbon, properly chosen, may turn out to be sufficient to determine all its more important physical properties. Clearly, therefore, one must start with a knowledge of the properties of individual hydrocarbons, interpreted and generalized in the light of these correlations.

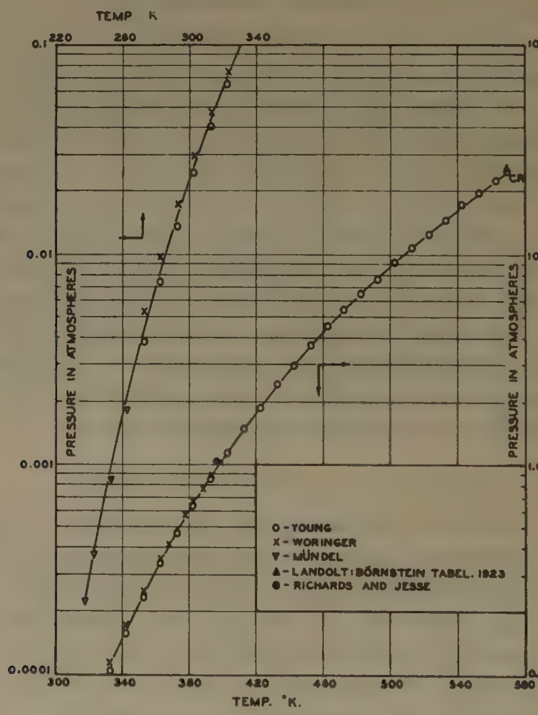

Fig. 1.—Vapor pressure of *n* octane (C_8H_{18}).

It must be emphasized that these correlations are not absolute. They are approximations only. However, many of them are remarkably close, almost always amply within the requirements of engineering work and in some cases probably better than the accuracy of the best existing data.

Vapor Pressures

The vapor pressures of all hydrocarbons rise rapidly with increase in temperature, so rapidly that when plotting them on ordinary coordinate

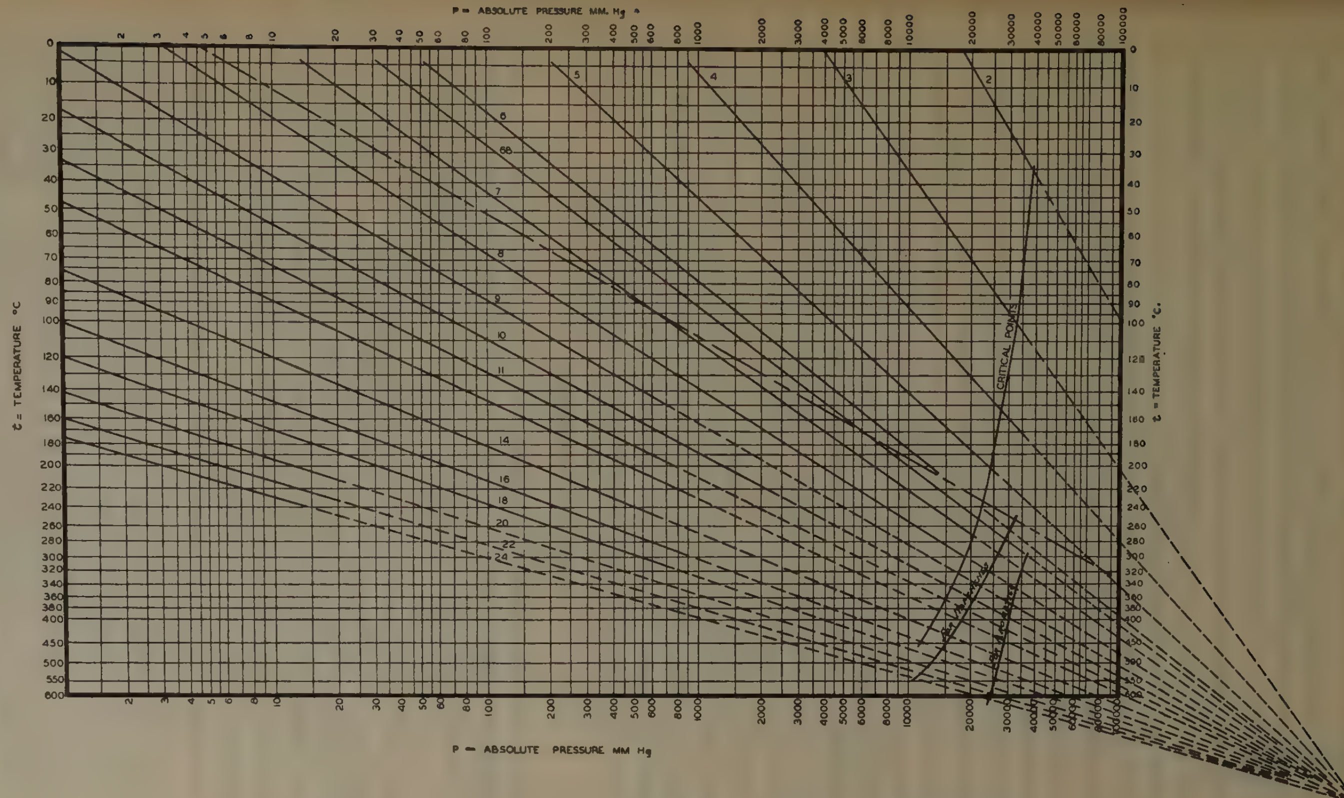

FIG. 2.—VAPOR PRESSURES OF NORMAL PARAFFIN HYDROCARBONS.

Original article by Cox: *Ind. & Eng. Chem.* (1923) **15**, 592. Data of Wilson and Bahlke: *Ind. & Eng. Chem.* (1924) **16**, 115. Extended ranges, Calingaert and Davis: *Ind. & Eng. Chem.* (1925) **17**, 1287. Key numbers are values of $C_nH_{2n} + 2$. Steam indicated by broken line. Benzene 6B.

Equations of scales: Ordinates, $Y = 3910\left[\frac{1}{230} - \frac{1}{230 + t}\right]$ = inches; abscissas, $x = 4.03 \log_{12} P$ = inches.

paper interpolation is inaccurate and all precision is lost at low pressures. This difficulty can be met by the use of a semilogarithmic plot such as that of Fig. 1, which shows the vapor-pressure curve of *n*-octane. On this curve are indicated the data points of individual investigators, so that the correlation between their results is immediately apparent. All vapor-pressure data are of this general type and are probably best presented in this or some equivalent way.

Numerous methods of correlation of the vapor-pressure relationships of various hydrocarbons have been suggested. One of the most convenient is that of Cox, or one of its modifications, as shown in Fig. 2. The pressure scale is logarithmic and the temperature scale arbitrarily drawn. It is found that on such a chart the vapor-pressure curves of all pure hydrocarbons plot as substantially straight lines, converging to a common point. Consequently, a single point on the vapor-pressure curve of a hydrocarbon, such as its boiling point at atmospheric pressure, or at any other known pressure, enables one to construct the complete curve for the hydrocarbon in question. There is no doubt that this correlation is not perfect. The lines for individual hydrocarbons are certainly not always straight. Indeed, the vapor-pressure curves of some hydrocarbons cross each other, a fact incompatible with the chart. Furthermore, there are more dependable correlations, but these are also more complicated and since it is uncertain that they are more dependable when extrapolated to higher hydrocarbons, direct data on which are nonexistent, Fig. 2 is perhaps preferable for engineering work.

Critical Conditions

When hydrocarbon liquids are heated they expand. However, the vapor pressure increases rapidly and, on account of this fact, despite the rise in temperature, the density of the saturated vapor in equilibrium with the liquid increases. Finally, a point is reached at which the densities of liquid and of saturated vapor become identical and differences in physical properties disappear. This is called the critical point of the material in question, the temperature being the critical temperature T_c, the pressure, the critical pressure P_c, and the volume, the critical volume, v_c. The critical temperature and pressure are shown for octane at the right-hand end of the curve of Fig. 1, marked Cr.

The correlations of critical conditions are somewhat less satisfactory than those of vapor pressures. However, the value of the so-called critical ratio, RT_c/P_cV_c, is remarkably constant for all hydrocarbons investigated. Its average is about 3.79. For hydrocarbons with less than four carbon atoms per molecule the value is definitely lower, being about 3.59 for ethylene and ethane and 3.46 for methane. However, for hydrocarbons with four carbon atoms and above per molecule, the deviations apparently never lie outside the range 3.7 to 3.85, a variation

from the mean of only 2 per cent. While it is true that within this range the values for paraffin hydrocarbons average high and those for the aromatics low, it seems allowable, until more accurate data are available, to use the average figure, 3.79, for the critical ratio. It has also been shown that at the critical point the density of all paraffin hydrocarbons containing more than three carbon atoms per molecule on which data are available is practically the same, 0.236. It is readily shown that this is equivalent to the statement that for these hydrocarbons the value of the ratio MP_c/T_c is equal to 5.0 within the experimental error. Apparently for aromatic hydrocarbons with no side chains this ratio has a value of approximately 6.9, and for naphthenic ring compounds without side chains about 6. Granting that the vapor-pressure curves can be represented by Fig. 2, this relationship immediately makes it possible to construct the critical curves for these three classes of compounds. The corresponding curves are shown on the figure.

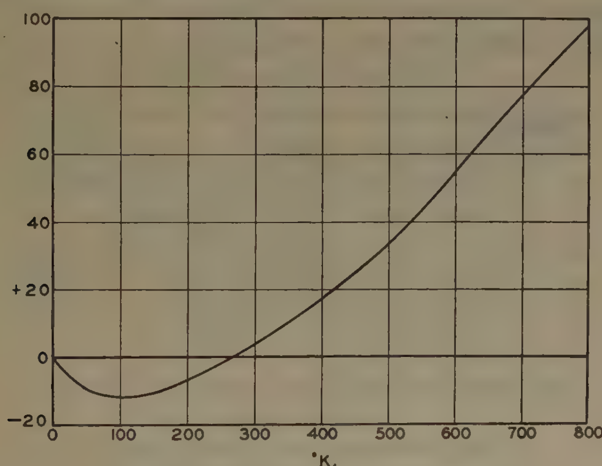

FIG. 3.—DELTA CORRECTION FACTOR.

Another method of prediction of critical temperatures is that of Watson.[1] He has shown that the critical temperature is given with remarkable precision by the formula

$$T_c = \frac{T_s + \Delta}{0.283(M/d_s)0.18}$$

T_s is the atmospheric boiling point of the material on the absolute scale (deg. K), M is its molecular weight and d_s its specific gravity at its atmospheric boiling point. Δ is a correction factor, depending on the normal boiling point only, which may be read from the curve of Fig. 3. It is true that this method of calculation requires the specific gravity of the

[1] *Ind. & Eng. Chem.* (1931) **23**, 361; (1933) **25**, 880.

material at its atmospheric boiling point; this can be measured directly, or calculated from the density at normal temperatures by the known coefficient of expansion.

Vapor Densities

At very low pressures the vapors of all hydrocarbons follow the gas laws, most conveniently written in the form $PV = nRT$. As pressures increase, deviations begin to develop, and for all hydrocarbons at normal temperatures the densities are greater and the volumes less than those calculated from the gas laws. The data available are none too extensive, but analysis of them by various investigators during the last few years has shown that they can be correlated very satisfactorily on the basis of the critical values of the individual hydrocarbons. This is done by assuming that the relation between pressure, temperature and volume of any pure hydrocarbon can be represented by the gas-law equation by the introduction of a correction factor μ, writing $PV = \mu nRT$. If, now, the pressure P, under which the hydrocarbon exists, is expressed as a

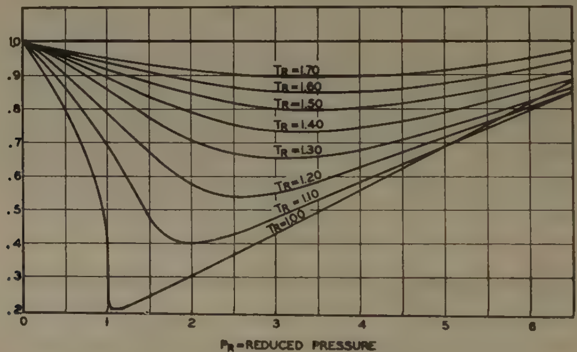

FIG. 4.—TEMPERATURE-PRESSURE CURVES.

fraction of the critical pressure P_c, the fraction $P_R = P/P_c$, being called the reduced pressure, and the temperature similarly as a fraction of the critical temperature, i. e., as a reduced temperature, $T_R = T/T_c$, it is found that for all hydrocarbons having more than three carbon atoms per molecule the correction factor μ to the gas laws is a unique function of the reduced temperature and pressure given by the curves of Fig. 4. Clearly, this puts one in a position to evaluate the volume or density of any pure hydrocarbon vapor under any conditions of temperature and pressure, provided one knows its critical constants.

Replotting the data on which Fig. 4 is based shows that at high pressures the so-called isometrics—the curves of pressure against temperature at constant volume—are substantially straight lines over considerable ranges. Furthermore, if these are plotted on a reduced basis, for instance as P_R vs. T_R at constant V_R, as is done in Fig. 5, it is found that

all higher hydrocarbons (those having more than three carbon atoms per molecule) fall on a single diagram. Figs. 4 and 5 are equivalent and represent merely different ways of expressing the same relationships. In use, sometimes one and sometimes the other is found the more convenient.

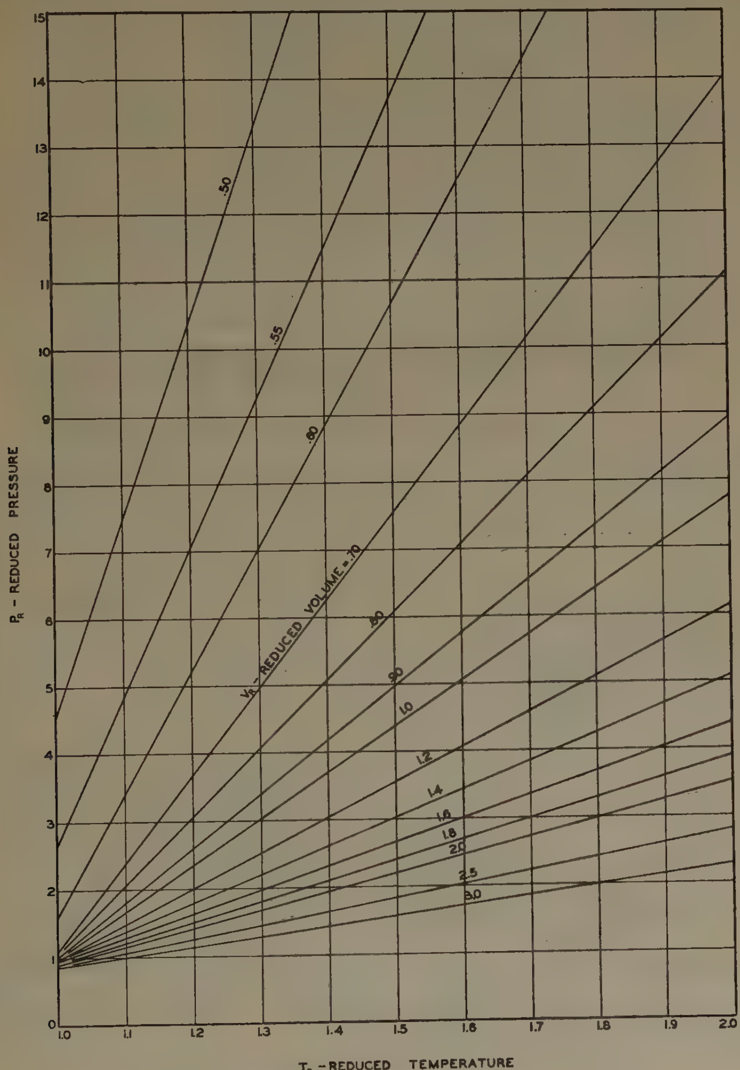

FIG. 5.—REDUCED TEMPERATURE-PRESSURE CURVES.

Thermal Properties

General correlations are available of the specific heats of hydrocarbon liquids and of their vapors under pressures sufficiently low so that

deviations from the gas laws may be neglected.[2] A useful correlation of the heats of vaporization that is valid so long as the vapor pressure is not too high is the Hildebrand function, shown in Fig. 6. Fig. 4 shows

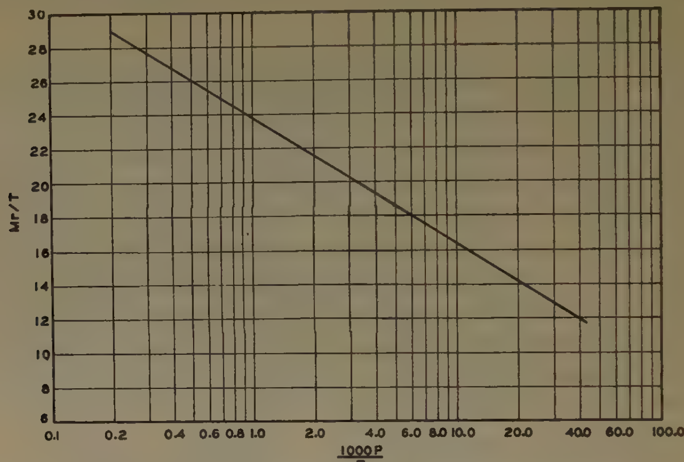

FIG. 6.—HILDEBRAND FUNCTION FOR HYDROCARBONS.

the very large deviation from the gas laws suffered by the vapors at high pressures, and deviations from their thermal behavior at low pressures are to be expected. It is readily shown thermodynamically that the correction for the effect of pressure can be expressed in the relatively simple terms of Fig. 7. In any operation involving the heating or cooling of a vapor, calculate the heat effect on the assumption that the operation is conducted at pressures low enough to neglect deviations from the gas laws and then at each end of the operation apply a pressure correction of which the magnitude depends upon the reduced volume as

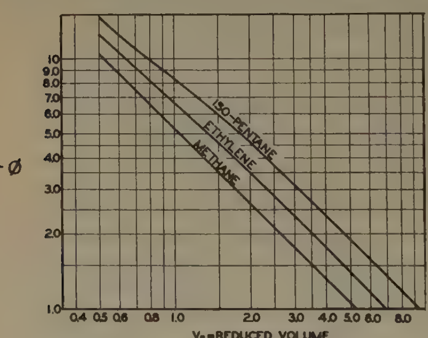

FIG. 7.—CORRECTION FOR EFFECT OF PRESSURE.

shown in the following equation. The term ϕ is given by Fig. 7. Notice that its negative value is plotted in the figure. The isothermal pressure correction to the internal energy is

$$\Delta E = \mu_c R T_c \phi$$

Hence, to calculate the change in internal energy due to pressure alone, for hydrocarbons with more than three carbon atoms per molecule,

[2] Parks and Huffman: Free Energies of Some Organic Compounds, 68. Chem. Cat. Co., Inc. 1932.

multiply the difference in the ordinate readings of Fig. 7 corresponding to the actual change in V_R by the term $\mu_c RT_c = 0.264RT_c$. Its evaluation requires knowledge of T_c for the hydrocarbon in question.

Fugacities

For the computation of the reversible, isothermal work of compression of a perfect gas one uses the familiar formula,

$$W = nRT \ln p_2/p_1 = p_1v_1 \ln p_2/p_1$$

In view of the large deviations from the gas laws at high pressures indicated by Fig. 4, it is not surprising to find that this equation breaks down completely under these conditions. If, however, one will use in it under the logarithmic term a properly corrected pressure, f, the equation can still be employed in this form for the exact calculation of isothermal reversible work. It thus becomes $W = nRT \ln f_2/f_1$. At pressures low enough so that the deviations from the gas laws are negligible, correction of the pressure is unnecessary and f becomes numerically identical with

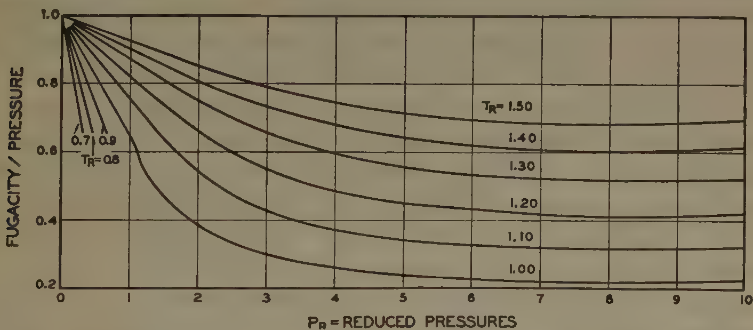

FIG. 8.—RATIO OF FUGACITY TO PRESSURE.

p. The pressure thus corrected is called the fugacity. It is easily shown that for compounds conforming to Fig. 4 the ratio of the fugacity of the material under given conditions to its pressure f/P is a function of the reduced temperature and reduced pressure only. This function has been computed and is presented graphically in Fig. 8. From this figure, if one knows the reduced pressure and temperature of the material, one is immediately in a position to read off this ratio, f/P, and by multiplying by the pressure to obtain the fugacity f itself.

While the fugacity is a convenient function for calculating the work of isothermal, reversible compression, its utility is far greater than this, as will appear from further discussion.

It is well again to emphasize the fact that in order to use all these relationships, at least above the pressure range in which deviations from the gas laws may be neglected, one must know the critical temperature and pressure of the hydrocarbon with which one is dealing, in order to be

able to calculate the reduced temperatures and pressures, knowledge of which is essential for solution of the problem. Furthermore, unless the critical condition of the hydrocarbon in question has been determined experimentally, it must be evaluated by indirect relationships and for this evaluation one usually requires the knowledge of three characteristics of the hydrocarbon, of which the most convenient are its atmospheric boiling point, its density at that temperature, and its molecular weight. It is important to form the habit of securing these three items of data concerning any hydrocarbon in the behavior of which one is interested.

It is well to emphasize the fact that the relations discussed up to this point apply only to pure hydrocarbons and cannot be applied directly in these forms to mixtures.

Properties of Hydrocarbon Mixtures

From the point of view of vaporization, the behavior of a specific hydrocarbon mixture is shown in Fig. 9. This figure represents the data on binary mixtures of pentane and heptane. The left-hand curve is the vapor-pressure curve of the former and the right-hand curve of the latter, each in the pure state. The intermediate curves represent the behavior of three specific mixtures of the two components, the composition of each mixture being indicated on its curve. If a pure substance is heated to its boiling point it can be transformed completely into vapor without change in either pressure or temperature, but the behavior of a mixture is usually otherwise. If the temperature of a liquid mixture is raised at constant pressure, or if the pressure on it is reduced at constant temperature, a point is reached at which vaporization starts, which is called the boiling point of the mixture.[3] In general, if further heat is applied, maintaining the same limitations of operation, evaporation proceeds, but, unlike the behavior of a pure material, the temperature continues to rise at constant pressure or the pressure to fall at constant temperature. Ultimately, however, the liquid phase disappears and the process of vaporization completes itself. If the same mixture is held at a temperature sufficiently high and pressure sufficiently low, it will exist entirely in the form of vapor. If, now, the temperature of this mixture is lowered at constant pressure or its pressure increased at constant temperature, a point called the "dew point" will be reached at which condensation starts. The dew point is the end point of the process of vaporization described above. The three loop curves of Fig. 9 represent the evaporative behavior of the mixtures of pentane and heptane specified. The upper limb of each loop is the boiling-point curve of the

[3] In the petroleum industry this is usually called the initial boiling point, to distinguish from the conditions obtained after a certain fraction of the mixture has been evaporated and removed from the system.

mixture in question and the lower limb its dew-point curve. The top curve of the diagram, extending between the critical points of the components, is the locus of the points at which corresponding boiling-point and dew-point curves meet. At these points the mixture has the same density and other physical properties as vapor and as liquid and two phases differing in properties can no longer exist in equilibrium with each other. These points are critical conditions for the mixtures. However, the right-hand extremity of each loop is the maximum temperature at

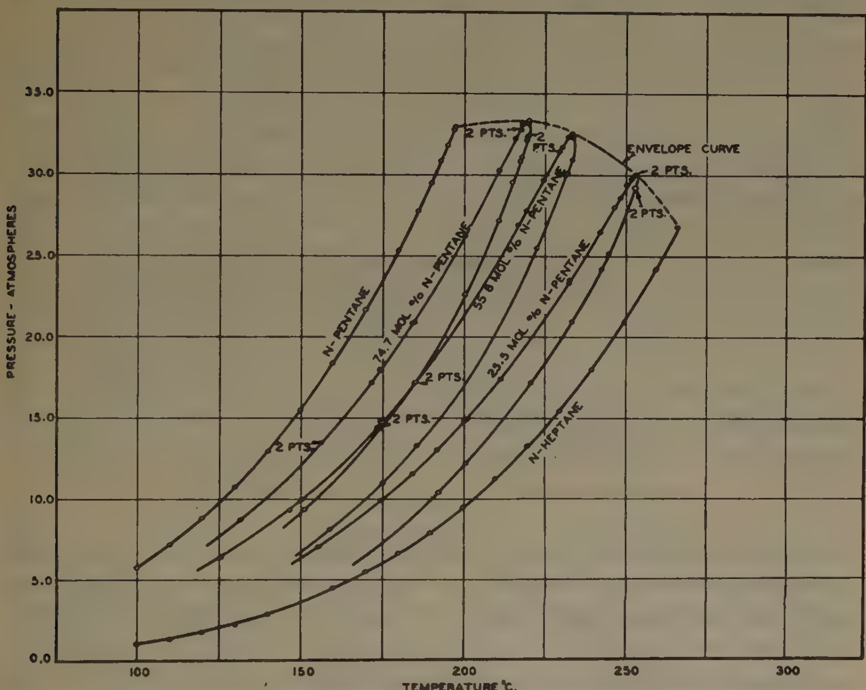

FIG. 9.—PRESSURE-TEMPERATURE DIAGRAMS AT CONSTANT COMPOSITION FOR n PENTANE—n HEPTANE SYSTEM.

which any condensation whatever is possible from each specific mixture and consequently likewise represents a critical condition. The points of the first group are called the Cr. 1 points of the mixtures and those of the second, the Cr. 2 points. For pure components the two become identical.

These curves have been determined for only a relatively small number of hydrocarbon mixtures and almost all of these were limited to binary mixtures. Consequently, at first one would consider unjustifiable generalization to the extraordinarily complex mixtures encountered in crude petroleum. However, theoretical considerations based on the phase rule lead to the conclusion that all ordinary mixtures of hydro-

carbons, however complex, should have boiling-point and dew-point loop curves of exactly the type shown in Fig. 9, differing only in that the presence in the mixtures of components varying enormously in volatility greatly widens the range of the diagram. This conclusion is fully substantiated by the limited amount of experimental work that has been done. Consequently, one can with assurance look upon these loop curves as representative of the behavior of hydrocarbon mixtures under changes in pressure and temperature. However, the engineering utility of the relationships would be extremely limited were it not possible to put them on a satisfactory quantitative basis.

In order quantitatively to solve the problems of vaporization, one must be able to compute the vapor pressure and vapor compositions of liquid mixtures, and to do this one takes advantage of the so-called laws of perfect solutions. At low pressures these take the form of Raoult's and Dalton's laws. The former states that the partial pressure of a volatile component in a liquid is equal to its mol fraction in the liquid times its pressure at the same temperature in the pure state. The latter asserts the additivity of partial pressures, the total pressure of a vapor mixture being equal to the sum of the partial pressures of the components. The partial pressure of each component is the pressure it would exert at the same temperature in the same space in the absence of the others. In Raoult's Law, $p = Px$; in Dalton's Law, $\pi = \Sigma p$. Combined with Avagadro's Law, these are equivalent to

$$p = Px = \pi y$$

For any conditions in which these equations are applicable they make it possible to calculate the initial boiling point and the dew point of any mixture of known composition, the composition of liquid and vapor in equilibrium with each other and the percentage of the total mixture in the form of liquid and vapor for any specified condition. This is true even of mixtures of extreme complexity, because it has been shown that such mixtures can be characterized in terms of the so-called true boiling-point curve; i. e., the boiling point of each individual constituent in the mixture plotted against the cumulative fraction of all constituents of lower boiling point, up to and including this particular temperature level, together with the boiling point-molecular weight relationship. Beginning in the light naphtha range and above, petroleum mixtures behave as though they consisted of an indefinitely large number of components, differing only differentially in boiling point. However, each differential portion can be treated as an infinitesimal amount of a pure component. Its vapor-pressure curve can be estimated, by means of the Cox chart, because one point on this curve is known; namely, the boiling point. Its molecular weight makes it possible to convert weight fraction into mol fraction. Thus, one is in a position to evaluate the differential partial

pressure of each constituent, however small its amount, and obtain total pressures and vapor compositions by graphic integration.

The computation methods just outlined suffer from the limitation that they are grossly inaccurate at high pressures, particularly above a few hundred pounds, a situation that renders them almost useless for the production engineer. This situation is overcome through generalized methods of correction of the solution laws for the effect of pressure, based upon the high-pressure behavior of pure hydrocarbons discussed above. While the solution laws in the familiar form given above, $p = Px = \pi y$, break down at high pressures, they can still be used in the same form if, instead of the pressure terms which they contain, the fugacities are substituted. The fugacity applies only to a single component and never to a mixture as a whole. Thus, a mixture exerts a total pressure but possesses no such thing as a total fugacity. In a mixture, therefore, under pressures low enough for the use of the gas laws, the fugacity of the component is the equivalent of its partial pressure. The fugacity is designated by the letter f. The subscript P indicates the fugacity of the pure component at the temperature in question and π, its fugacity in the pure state at the total pressure π. Thus, the solution laws become $f_P x = f_\pi y$. On the assumption that hydrocarbon liquids mix isothermally without heat effect or change in volume, and that the same is true of hydrocarbon vapors at constant pressure, the fugacities to be employed in this equation can be computed from the properties of the pure hydrocarbons and, furthermore, it is possible to express them in terms of reduced temperature and pressure. The results thus computed are shown in Fig. 8. It is seen that the ordinates for this figure are the ratio of fugacity to the corresponding pressure. The fugacity itself is obtained by multiplying by the pressure. Since the fugacity is the corrected pressure, it is clear that the units in which the fugacity is expressed are those of the pressure by which this ratio is multiplied. This equation, together with the plots, makes it possible to calculate equilibrium concentrations of vapor and liquid under any conditions, irrespective of pressure, so long as the underlying assumptions are valid. However, it is important to point out that fugacities, unlike partial pressures, are not additive.

The validity of these relationships for hydrocarbon mixtures, both simple and complex, has been tested experimentally over considerable ranges and found on the whole dependable. However, deviations from the solution laws do occur, although among hydrocarbons they are usually relatively limited. They are most serious where the hydrocarbons in question differ most widely in structure; as, for example, between aromatic and paraffinic compounds. Efforts are under way to enable one to predict the effect of such differences, but the complete solution of this problem rests with the future. Fortunately, in a given

crude, the differences between constituents are usually at a minimum, thus tending to lessen divergencies from calculated behavior. These methods of computation are recommended as representing the best available in the present state of our knowledge.

At temperatures above the critical of any given component, these computation methods break down for that component in the sense that the component can no longer exist as a liquid in equilibrium with a saturated vapor of properties different from its own. However, it is well recognized that such components will dissolve in liquids and the question arises as to the mechanism of solution and the methods of computation.

As a case in point, one may well consider the solubility of methane in various hydrocarbon liquids, data on which have been obtained by Frolich. The results are summarized in Table 1.

TABLE 1.—*Solubility of Methane in Hydrocarbon Liquids*

Solvent	π Atmospheres	$P = \frac{y\pi}{x}$ Atmospheres	$f_P = \frac{yf_\pi}{x}$
Butane	18	147	143
	47	188	177
	60	201	184
Pentane	45	183	172
	75	212	185
	100	219	191
Hexane	34	169	161
	70	192	173
	90	211	185
Octane	22	155	149
	81	191	171
	104	214	186
Cyclohexane	20	345	335
	24	343	328
	48	308	288
	60	298	275
	71	300	270
Benzene	20	571	555
	40	482	454
	65	445	377
	80	426	377
	112	442	375

Column 3 gives the value of P calculated from the Raoult's Law equation, $P = \pi y/x$. While there is considerable fluctuation in the

computed values, for the paraffin hydrocarbons the average value is 190 atmospheres with an average deviation of 18 atmospheres. Cyclohexane shows a higher average, 320 atmospheres, whereas benzene shows 475 atmospheres, indicating a distinct trend with decrease in hydrogen-carbon ratio of the solvent. Granting one knows the character of the solvent, this table would put one in a position to calculate the solubility by the use of these computed values of P. Furthermore, if values thus computed are plotted against the temperature they are found to constitute, for a given type of solvent, a smooth extrapolation of the vapor-pressure curve for the liquid methane. This is true despite the variations in P for different solvents, because it is possible to extrapolate the vapor-pressure curve itself to widely different values, without doing violence to it, provided the excess temperature above the critical is sufficient. However, because of the high pressures involved there can be no logical justification for the use of the Raoult's Law equation, but rather should one calculate and employ an extrapolated value of the fugacity f_P, calculated from the equation $f_P = yf_\pi/x$. Knowing the temperature and total pressure π, the value of f_π/π can be read from Fig. 8, and f_π obtained by multiplying by π itself. This quantity thus calculated is shown in column 4 of the table. Here again for the paraffin hydrocarbons, f_P has a value of 173 atm. ± 12 atm. However, for benzene and cyclohexane the values are higher, as was the case with the corresponding values of P.

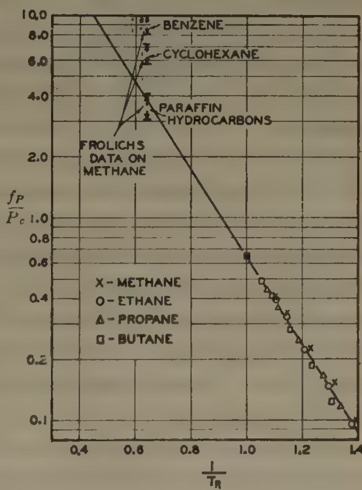

Fig. 10.—Reduced fugacities plotted on curve common to all hydrocarbons.

Objection may well be raised that these values are computed from data on the solubility of methane alone and apply to no other hydrocarbon. However, it is a well-known fact that at temperatures in the neighborhood of the critical the fugacities of the pure liquid hydrocarbons, expressed on a reduced basis, are all substantially the same function of the reduced temperature, although at low reduced temperatures marked divergencies develop. This being true below the critical temperature and the fugacities calculated from solubility data above the critical being smooth extrapolations of the fugacity curve below, one would expect the reduced fugacities to plot on a single curve common to all hydrocarbons. This has been done in Fig. 10. It will be noticed that the data for the four paraffin hydrocarbons plotted, methane to butane

inclusive, fall substantially on a straight line below the critical temperature and that the reduced fugacity of methane, calculated from its solubility in paraffin hydrocarbons at 25° C., the data for which are shown in Table 1, falls substantially on the extrapolation of that line. The data for the solubility in the paraffins are shown, not as a point, but as a line, the length of which indicates the maximum experimental deviation from the highest to the lowest of Frolich's points.[4] The probable error of course is less than half the length of this line. The data for cyclohexane and benzene are similarly indicated. For these two hydrocarbons the reduced fugacity curves would require some curvature above the critical temperature.

One is justified therefore in using Fig. 10 for the calculation of the solubility of any hydrocarbon in a hydrocarbon solvent at temperatures above the critical of the dissolving constituent, provided one knows the character of the solvent, whether paraffinic, naphthenic or aromatic. An even better method of approach is to use the line of Fig. 10 and, instead of measuring the average molecular weight of the solvent (which in production work is the crude oil) by the usual methods, measure experimentally the solubility of a gaseous hydrocarbon (for instance, methane, in the oil) and from this solubility calculate the molecular weight of the oil. In other words, the solution laws are not exact, but they can be rendered satisfactory for engineering purposes by various modifications. The two suggested above are: (1) to correct the fugacity curve for the character of the hydrocarbon solvent, or (2) to use an extrapolated fugacity curve and correct the molecular weight of the solvent.

The nature of the problem will perhaps be clarified by further study of Fig. 10. Clearly, that figure is equivalent to the extrapolation of the vapor-pressure curve of the liquid to temperatures above the critical point. Can any physical significance be ascribed to such an extrapolation?

As already pointed out, liquids usually mix with relatively little change in volume and in hydrocarbons the change is less than the average. However, when gaseous methane dissolves in oil under ordinary conditions, it is certainly mixing with it, and yet the mixing is accompanied by an enormous change (shrinkage) in total volume. If the methane were compressed sufficiently prior to solution in the oil, it could be brought to a volume so low that solution in the oil would occur without change in total volume. In this sense the compressed methane would act as a liquid from the point of view of perfect solutions. Therefore, despite the fact that the methane is above its critical temperature, it is legitimate

[4] The deviations are due partly to a quite definite trend of the calculated values of f_P with the pressure, the tendency being for it to rise with the pressure for the paraffin hydrocarbons and fall in the case of cyclic compounds. Were the solubilities in different members of a given group of compounds compared at the same total pressures, the deviations would be much less.

to call it a liquid. In other words, a gas dissolving in a liquid solvent dissolves, not as a gas, but in a highly condensed condition that is truly described as a liquid state. In this sense, granting the operation of the solution laws, the extrapolated vapor pressure, or rather the total pressure corresponding to the extrapolated fugacity, is the pressure under which gaseous methane will possess a density that will enable it to mix with the liquid hydrocarbon solute without change in total volume. In other words, under this pressure, from the point of view of solution, the methane, despite the fact that it is above its critical temperature, is in the liquid state. By the use of Fig. 4 it is easily possible to calculate the density of methane at the pressure corresponding to the extrapolated fugacities of Fig. 10. Dr. Lacy has measured the increase in volume of gasoline and isopentane on solution of methane in them and calculated the corresponding density of the methane, obtaining for isopentane 0.0027 c.c. of methane in the dissolved state for each c.c. of methane gas at atmospheric pressure and 30° C., corresponding to a specific gravity of the dissolved methane of 0.239. The corresponding figures for gasoline are 0.00218 c.c. of methane in the dissolved state for each cubic centimeter of methane gas, corresponding to a specific gravity of dissolved methane of 0.295. The Bureau of Mines has published similar data on solubility of natural gas in oil. The densities calculated from its data are 0.384 for Bartlesville crude, 0.366 for Inglewood crude and 0.479 for Seminole. The natural gas contained 14 per cent of ethane and higher; obviously higher densities would be expected for this gas than for pure methane. Using the line of Fig. 10, the corresponding density of methane is 0.164. Using the curve through the cyclohexane data, representing an extrapolation of the points below the critical temperatures, gives a figure of 0.24, and a similar computation based on the data on benzene of Frolich gives a figure of 0.28. The density of methane computed from Frolich's solubility corresponds surprisingly closely with the direct measurements of liquid volume available.

This behavior of dissolving gases can be approached from another angle. Thus, it is a well recognized rule that the heat of solution of a hydrocarbon vapor dissolving in a liquid solvent is practically identical numerically with the heat of vaporization of the dissolving constituent at the same temperature. At the critical temperature heat of vaporization becomes zero and above the critical temperature in the usual sense of the word the concept breaks down. None the less, it is a well-known fact that even far above the critical temperature dissolving gases do possess heats of solution. In fact, the heat of solution of a gas or vapor is the negative of the heat of expansion of the component from the liquid to the vapor state. This heat of expansion is the change of internal energy given by Fig. 7, plus the change of the pressure-volume product. In this sense one can describe the heat of solution of a gas in a liquid, at

temperatures above the critical of the dissolving component as the negative isothermal heat of vaporization of the gas compressed to its liquid density, when expanded to the conditions corresponding to the lower pressure at which it is dissolved.

Attention should be called to the fact that at the moderately high pressures and low temperatures encountered in production work, the amount of a given constituent present in the gas phase decreases extraordinarily rapidly as the boiling point of that constituent rises. Under usual conditions the amount of butane in the gas is negligible. Obviously, as the pressure falls constituents of higher boiling points will enter the gas in progressively increasing amounts but the quantities are computed by the same technique. The conditions of temperature and pressure with which the production engineer is dealing make his problems from this angle far simpler than those of his fellow refinery engineers.

To illustrate the utility of this method of approach in the attack of production problems, let it be assumed that a well is producing a crude of 39° A.P.I., the character of which is indicated by the true boiling-point curve shown in Fig. 11. The average molecular weight of this oil is found to be 180. These data apply to a sample as it was separated at the top of the well from the gases at substantially atmospheric pressure at 79° F. The well is producing with a gas-oil ratio of 613 cu. ft. per barrel, the gas volume being reduced to 30 in. of mercury and 60° F. The analysis of the gas as it was separated from the oil is 80.9 per cent methane, 10.1 per cent ethane, 6.8 per cent propane and 2.2 per cent butane. The composition of the oil in weight per cents is: methane 0.045, ethane 0.05, propane 0.147, butane 0.290, pentane and higher 99.468. Let it be required to calculate the volume of gas plus oil flowing through the face of the sand at the bottom of the well, first, on the assumption that the temperature at the bottom of the well is 140° F., and the pressure at that point is 735-lb. gage, and, second, that the temperature is 80° F. and the pressure 735-lb. gage.

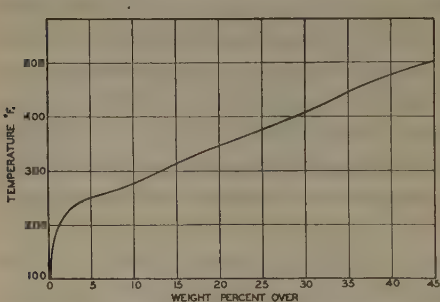

FIG. 11.—TRUE BOILING-POINT CURVE OF THE CRUDE.

Consider for the moment one barrel of this oil plus the gas associated with it. The oil weighs $42 \times 8.33 \times 0.83 = 290$ lb. Since the experimentally determined molecular weight of the oil was 180, one barrel of the oil is $^{290}/_{180} = 1.615$ lb. mols. Associated with the oil is 613 cu. ft. of gas. Since 1 lb. mol of gas occupies 378 cu. ft. at 30 in. of mercury and 60° F., the mols of gas are $^{613}/_{378} = 1.62$. It will be more convenient to consider, not a barrel of oil, but 1 lb. mol of the combined oil and gas.

One barrel of oil corresponds to 1.62 + 1.615 mols of gas plus oil, or 3.235 mols total. Hence, in each mol of the mixture of oil and gas there is 0.501 mol of gas and 0.499 mol of oil.

Since the analysis of the oil is given on a weight per cent basis, it will be desirable once again to shift gears and consider 100 lb. of the oil. This 100 lb. constitutes $^{100}\!/_{180}$ = 0.556 lb. mols. The 100 lb. contains 0.045 lb. of methane which constitutes 0.045/16 lb. mols of methane. Consequently, the mol fraction of methane in the oil is this figure divided by 0.556 or 0.005. Since one mol of the mixture of oil and gas contains 0.499 mols of oil, multiplying the molal fraction of methane in the oil by this last figure gives the actual pound mols of methane in the oil. Table 2 summarizes the results of similar calculations for the various components.

TABLE 2

	Mols in Gas	Mols in Oil	Total Mols
C_1	0.405	0.0025	0.407
C_2	0.051	0.0015	0.053
C_3	0.034	0.0030	0.037
C_4	0.011	0.0045	0.015
C_5 and higher		0.4875	0.488
	0.501	0.4990	1.000

Table 3 summarizes the preliminary computation for conditions of 140° F. and 735 lb. pressure: the steps in calculation should be obvious from the preceding discussion. All pressures are given in pounds per square inch.

TABLE 3.—*Preliminary Computation for Conditions of* 140° *F. and* 735 *Lb. Pressure*

Component	T_c	P_c	T_R	P_R	π_R	f_P/P	f_P	f_π/π	f_π	α
C_1	191	674	1.74		1.11	5.3[a]	3560	0.94[b]	704	5.06
C_2	305	718	1.09		1.04	0.94[a]	675	0.74[b]	555	1.22
C_3	369	632	0.903	0.488	1.18	0.76[b]	234	0.40[c]	300	0.78
C_4	426	528	0.782	0.195	1.41	0.83[b]	85	0.34[c]	255	0.33

[a] Read from Fig. 10 as f_P/P_c.
[b] Read from Fig. 8 as f_P/P—can also be obtained from Fig. 10.
[c] Extrapolation of Fig. 8.

Still focusing attention on 1-lb. mol of combined gas and oil flowing from the well, but realizing that this mixture will be partly vaporized at 140° F. and 735 lb. pressure, despite the fact that the amount of vaporization will be far less than that existing at the top of the well, call the

total mols vaporized at the face of the sand N, the mols of any one component vaporized under those conditions n, and the total mols of that component existing in the total mixture n'. The component to which one is referring in any given instance will be indicated by a subscript; n_1 is the mols of methane in one mol of total mixture existing in the form of vapor under the conditions in question. Clearly, n' is for each component the figure found in the last column of Table 2. Since one mol of total mixture is being considered, of which N mols are in vapor form, it follows by difference that $1 - N$ must be the total mols of liquid. Similarly, for each component $n' - n$ is the mols of that component in the liquid state.

TABLE 4

Component	n'	Assume $N = 0.316$	μ	V, Cu. Ft.	Comp. of Gas, Per Cent
C_1....................	0.407	0.285	0.87	2.38	90.24
C_2....................	0.053	0.019	0.63	0.10	5.98
C_3....................	0.037	0.010	0.1	0.01	3.15
C_4....................	0.015	0.002	0	0	0.63
		0.316		2.49	100.00

Since one has N mols of vapor containing n mols of a given constituent, it is clear that the mol fraction, y, of that constituent in the vapor is $y = n/N$. Similarly, the mol fraction of the same constituent in the liquid is $x = (n' - n)/(1 - N)$. Since, from the solution laws, $xf_P = yf_\pi$, it follows that

$$\frac{f_P}{f_\pi} = \frac{y}{x} = \frac{n}{n' - n}\left(\frac{1 - N}{N}\right) = \alpha$$

The ratio, f_P/f_π, is conveniently designated α because this ratio occurs repeatedly in the process of computation.

The last equation of the preceding paragraph is soluble by trial and error. If one will guess the total amount of vapor existing in the mixture N, then for each component n becomes the only unknown in the equation and, therefore, can be immediately computed for each. Clearly, the sum of the individual values of n must add up to the value of N. If they do not so add up, the value of N assumed was wrong and a new value must be taken until the required check is obtained. The technique of computation will be clear from the second column of Table 4, which represents the last step in the process of trial and error when the assumed value of N is correct. However, after a little experience the estimation of N becomes rapid, since as soon as one has calculated the check (or lack of it) for a couple of values of N, one can readily extrapolate to almost exactly the value required in the equation.

Since Table 4 gives the correct value of the total amount of vapor and the amount of each constituent, by the use of the gas law one is immediately in a position to compute the total volume. One needs to know only the volume that each of the constituents would occupy at the same temperature and total pressure computed from the gas laws with the μ correction. Since T_R and π_R are available for each constituent in Table 3, the value of μ can be read directly from Table 4, and the volume corresponding thereto calculated from the corrected gas-law data. This has been done in the fourth and fifth columns of Table 4. In other words, each mol of oil plus gas flowing from the well contains 0.316 mols in the vapor state and the volume of this vapor is 2.49 cubic feet.

The oil at the bottom clearly consists of the oil from the casing increased by the constituents of the gas dissolved in it because of the higher pressure at the bottom of the well. The amount of these dissolving constituents is computed in Table 5.

TABLE 5.—*Dissolving Constituents*

	Mol Wt.	Mols	Pounds
Oil at top	180	0.499	89.8
C_1	16	0.120	1.9
C_2	30	0.032	1.0
C_3	44	0.024	1.1
C_4	58	0.009	0.5
			94.3

One could compute the volume of each dissolving constituent and determine the total volume of the mixture by adding up that of the component but it is probably sufficiently accurate to estimate the decrease in specific gravity of the oil. Calling it 0.8, its volume at the bottom of the well is clearly $94.3/(62.4)\ (0.8) = 1.89$ cu. ft. Consequently, the total volume of oil plus gas is 4.38 cu. ft. It is interesting to note that under these conditions the volume of the gas is only 31.7 per cent greater than that of the oil, despite the fact that on a molal basis over 31 per cent of the total mixture is in gaseous form. Had this 31 per cent existed in gaseous form at atmospheric pressure and 140° F., the volume of the gas would be over 70 times that of the oil.

Tables 6, 7 and 8 repeat the computation for the same pressure with a lower temperature of 80°. The significant fact in the result is that this drop in temperature of only 60° F. has reduced the volume of the gas about 40 per cent.

It is clear that by such a technique the volume of both gas and oil in the crude flowing from a well can be calculated as a function of the pres-

sure at the point in the sand in question, provided one knows the sand temperature. Certainly, this information is essential in any adequate analysis of the mechanism of flow through the sand in all those important cases in which both liquid and gaseous phases are present. However, it ought to be emphasized that the computation method discussed here assumes no serious segregation of oil from the gas in the sand itself but that the two are sufficiently intimately mixed to maintain substantial equilibrium.

Table 6 summarizes the preliminary computation for conditions of 80° F. and 735 pounds pressure.

TABLE 6.—*Computation for Conditions of 80° F. and 735 Lb. Pressure*

Component	T_R	P_R	π_R	f_P/P	f_P	f_π/π	f_π	α
C_1	1.57		1.11	3.9[a]	2620	0.95	712	3.68
C_2	0.983		1.04	0.6[a]	430	0.62	465	0.925
C_3	0.813	0.228	1.18	0.86[b]	124	0.36[c]	270	0.46
C_4	0.703	0.075	1.41	0.92[b]	36	0.27[c]	202	0.18

[a] Read from Fig. 10 as f_P/P_c.
[b] Read from Fig. 8 as f_P/P. (Can also be obtained from Fig. 10.)
[c] Extrapolated from Fig. 8.

TABLE 7

Component	n'	Assume $N = 0.228$ n	μ	V, Cu. Ft.	Composition of Gas
C_1	0.407	0.212	0.93	1.52	92.98
C_2	0.0503	0.011	0.2	0.02	4.82
C_3	0.037	0.004	0.1	0	1.76
C_4	0.015	0.001	0	0	0.44
		0.228		1.54	100.00

TABLE 8

Component	Mol. Wt.	Mols	Pounds
C_1	16	0.193	3.1
C_2	30	0.040	1.2
C_3	44	0.030	1.3
C_4	58	0.010	0.6
Oil at top	180	0.499	89.8
		0.772	96.0

Estimating the specific gravity of the oil as 0.79, the total volume of the oil plus dissolved gas $= 96.1/(62.4)(0.79) = 1.95$ cu. ft. This makes a total volume of 3.49 cu. ft. of oil plus undissolved gas.

DISCUSSION

(*H. D. Wilde, Jr. presiding*)

H. D. Wilde, Jr.,* Houston, Tex.—These problems are becoming more and more important. The behavior of the Kettleman Hills and other deep reservoirs can be better understood in the light of studies such as Dr. Lewis has made. These data will be helpful in making volumetric corrections in proration requiring such corrections.

E. A. Stephenson,† Rolla, Mo.—This paper is one of the best illustrations of sound teaching I have seen.

C. E. Reistle,‡ Bartlesville, Okla.—This paper indicates the need of fundamental research. We should encourage research of this nature in order that we may definitely predict the behavior of hydrocarbon mixtures under high-pressure conditions. It seems particularly important to determine the physical and chemical properties of the hydrocarbons found in and associated with crude oil.

B. E. Lindsly,§ Bartlesville, Okla.—Take a high-pressure field with a gas cap at 3000 or 4000 lb. pressure. Wells drilled into such gas caps, notably in Kettleman Hills and Oklahoma City, have been known to produce large quantities of gasoline. This has puzzled many because it has been assumed invariably that high pressure causes condensation of the gasoline vapors and therefore high-pressure natural gas must necessarily be dry.

I wonder whether the phenomenon of retrograde condensation discussed by Dr. Lewis explains the production of large quantities of gasoline in the instances cited. If this is a proper explanation, and large quantities of gasoline vapor do exist in the gas caps of fields of very high pressure, it is easily possible that a small gas sample bled off at the well head might not be representative of the gas in the formation. In taking such a sample, it should be appreciated that gasoline will separate from the gas upon reduction of pressure, and care should be taken that such separation does not occur before the gas reaches the sampling apparatus, or that liquid gasoline is not lost during the process of sampling. Possibly the best way to get a gas sample from these "gasoline wells" is to take the sample at high pressure from the well head while the well is producing gas in considerable quantity, but not at a rate that will reduce appreciably the well-head pressure below its normal shut-in pressure.

Is it probable that the gasoline from these wells high on the structure of high-pressure fields originates directly from the gas contained in the gas cap, or is it more likely that the gasoline existed as a liquid in the formation?

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* Director of Production Research, Humble Oil & Refining Co.

† Professor of Petroleum Engineering, Missouri School of Mines and Metallurgy.

‡ Chairman, East Texas Engineering Association.

§ Senior Petroleum Engineer, U. S. Bureau of Mines.

Theory and Practice of Directed Drilling

By R. E. Allen,* Los Angeles, Calif.

(Los Angeles Meeting, September, 1933)

One of the most unusual oil-field engineering accomplishments of the past two years is the development and rapid advance in the directed drilling of wells. Directed drilling as referred to herein is the controlled steering of the drill stem in the required direction to a given location in the oil sand.

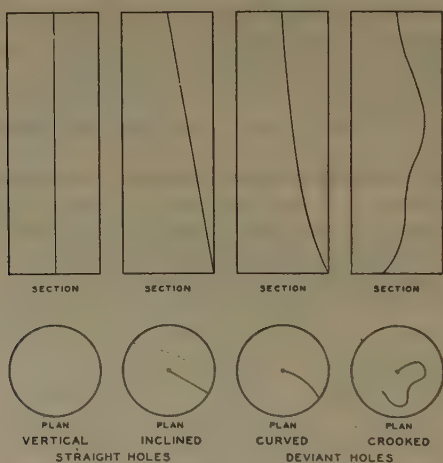

Fig. 1.—Types of holes.

The deliberate drifting of holes is an act so far removed from what has been considered good drilling practice that all of the old questions of correlation, drillability and production difficulties are revived. Only a few years ago, during the boom days of Seminole and Santa Fé Springs, the crooked-hole problem, as it was then called, occupied a primary position among the topics of the day in the fields of California and the Mid-Continent. The net result of all the discussion and study at that time was the conclusion that oil wells should be drilled with as little deviation from the vertical as possible and that crooked holes with elbows and dog legs were to be avoided because of the drilling and producing difficulties encountered therein, but that many nonvertical holes were slanting or angling rather than crooked and were not a serious problem.

* Assistant Oil Umpire of California.

Directed Drilling

Fig. 1 illustrates the general types of holes that may be drilled and explains why some nonvertical holes are not crooked and offer no particular drilling or producing difficulties because their course is such that no alternate reversing stresses are imposed on drill pipe, rods or tubing. The perfectly vertical hole is probably the scarcest thing in the oil fields and the slightly to severely crooked hole is probably the most common type because hole-straightening efforts frequently result in angular and directional changes and the consequent formation of a dog-leg hole.

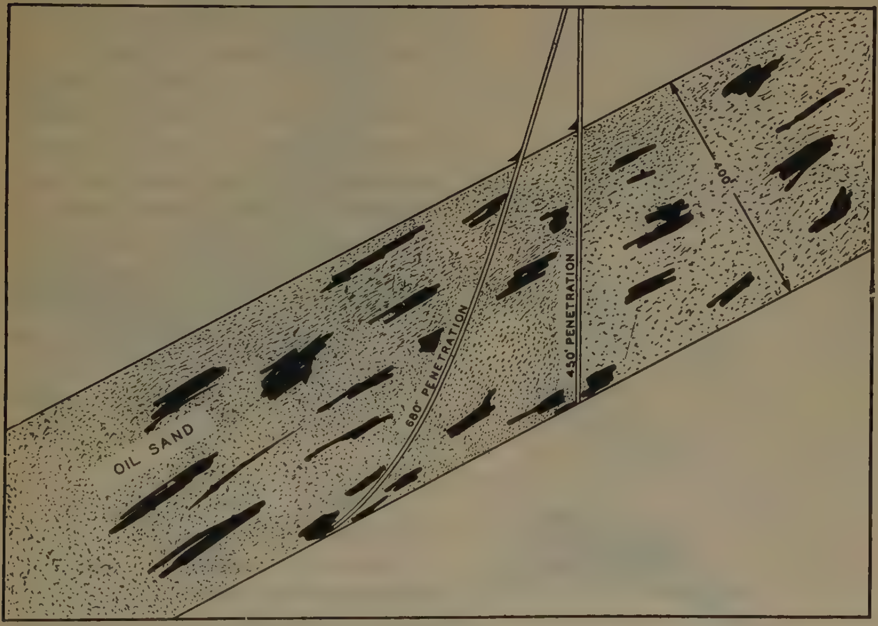

Fig. 2.—Relation of hole slant to oil-sand penetration.

The directed hole, if successfully controlled, may have no bends but rather a course gradually deviating farther and farther from the vertical so that when the oil-sand objective is reached it is not uncommon for holes to be 60° from the vertical.

Fig. 2 shows one practical application of directed drilling that may be, and has been, made in securing greater oil-sand penetration, with its current and ultimate effect on productivity.

Directed drilling, although still comparatively new in the oil-producing business, is a practice of many years standing in the mining of metals and nonmetals where it is common to drill several radiating holes from one location for the purpose of blocking out orebodies and mineral deposits. In mineral-survey holes the depths are relatively shallow com-

pared with deep oil wells, but the requirements of direction control and accurate hole surveys are even more exacting than with oil wells.

Advantages of Directed Drilling

Oil wells are not drilled primarily to survey the oil sand, so the only reasons for drilling deviant holes are to save expense or secure more oil production. Just as many other practices have both a proper use and an abuse, so has the directed drilling of oil wells. However, the use that may be made of the practice does not affect the consideration due it as a drilling accomplishment.

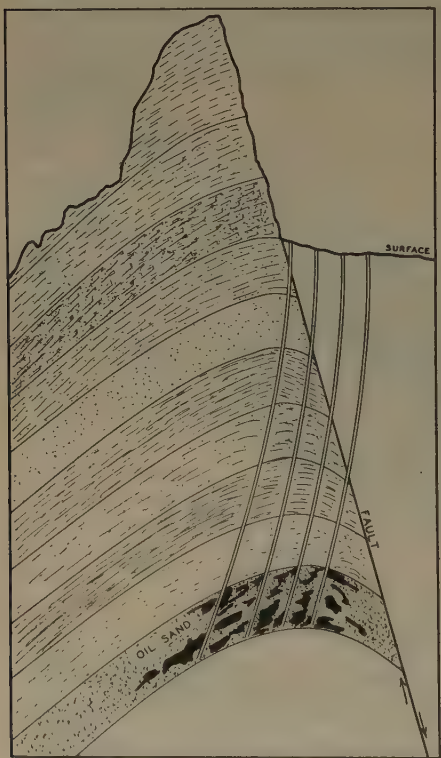

Fig. 3.—Use of directed drilling to overcome conditions of inaccessibility in Ventura County, California.

One use to which directed drilling may be put is that of avoiding the expense of drilling on an inaccessible surface location, such as a submerged or precipitous one, by using a more convenient and accessible location as a drilling site. Sometimes considerable depth of hole may also be saved by drilling from a topographically lower location, as shown in Fig. 3, which illustrates conditions in some Ventura County areas.

Another important use of directed drilling is found in offshore drilling in the ocean fields of California and the lake and bay fields of the Gulf Coast and Venezuela. In many such fields the cost of an adequate foundation for the derrick exceeds the cost of drilling the well. In such locations it is possible to drill several holes from one foundation and derrick and by properly directing the holes an area equal to that of six or seven normal locations may be penetrated and drained. The possibilities offered by directed drilling from isolated "steel islands" such as that pictured in Fig. 4 are most interesting. Such an island or pier-connected foundation may very well serve as the drilling site for seven wells as illustrated in Fig. 5, which indicates a plan for a reasonably vertical center hole surrounded by six holes sprangling out in as many directions, the general effect being that of a Maypole with six

ribbons leading down and away from the top of it. No serious mechanical difficulties confront such a practice and it is evident that the saving of expense would be considerable even though foundations cost no more than $40,000 each. Another saving that might be made lies in the possibility of drilling two holes simultaneously or at least concurrently. By exercising some ingenuity drill pipe might be run into an adjacent

Fig. 4.

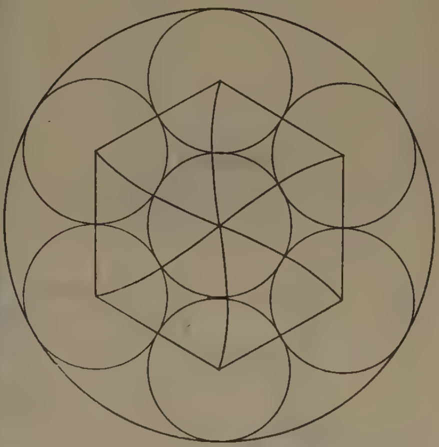

Fig. 5.

Fig. 4.—Drilling from an isolated steel island.
Fig. 5.—Diagram of multi-hole possibilities on a single location.

hole as pulled from one hole, thereby eliminating the racking of most of the pipe and virtually halving the combined round-trip time of the holes.

Practical Possibilities

Various actual applications of directed drilling are illustrated in Figs. 6 to 9 inclusive. Fig. 6 illustrates a condition where directed drilling has been used for crossing a fault to obtain production in the Mount Poso field. Fig. 7 is a generalized representation of conditions at Huntington Beach, where it is necessary also to drill through a fault to reach the oil that lies beneath inaccessible and submerged offshore locations. Fig. 8 illustrates a condition in the Long Beach field where one well is located so as to be unproductive if drilled vertically and had to be directed up-structure to obtain production, whereas the other well presents one of the most unusual cases known because of the fact that it drills upward into

the oil sand and shows a well in which the water excluded by the water string is really bottom water. High gas-oil ratios in the crest of the O'Connell zone at Santa Fé Springs led to the directing down dip of the well shown in Fig. 9, and a productive well with low gas-oil ratio was thus obtained.

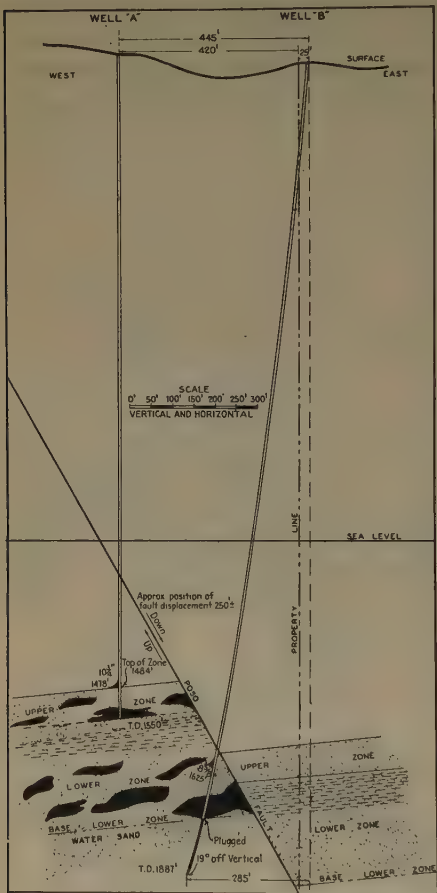

FIG. 6.—EXAMPLE OF DIRECTED DRILLING IN MT. POSO FIELD, KERN COUNTY, CALIFORNIA.

The foregoing uses and examples of directed drilling show its practical possibilities. Although the ethics or legal questions involved in directed drilling are not the concern of this paper, it may be remarked that the intentional crossing of property lines is generally considered to be an abuse of the practice because of the trespass thus committed. To discourage such abuse, laws have been proposed to the general effect that the deviation of a well shall not be sufficient to extend beyond the boundaries of the property on which it is located. Thus a large property would be the first essential of a directed-drilling program that was not intended to take oil belonging to others.

ACTUAL PRACTICE INVOLVED

The actual technique employed in directed drilling is based chiefly on experience, there being only a handful of men who can guarantee to complete a hole on any specified acre within a circle having the surface location of the well as its center and with a diameter equal to the vertical depth of the hole. The practical range of directed drilling is illustrated in Fig. 10, in which it is shown to be perfectly feasible to bottom a well at a distance from the derrick equal to approximately one-half of the depth of the well.

Next to experience the most important requisite of successful directed drilling is a knowledge of the position of the hole at all times. This information is supplied by the various well-surveying services that have established a reputation for accuracy and dependability. The actual drilling of the hole is done with the aid of such devices as bent drill collars

and drill singles, side hill and specially dressed bits, knuckle joints, fixed and removable whipstocks, variable drilling weights and other para-

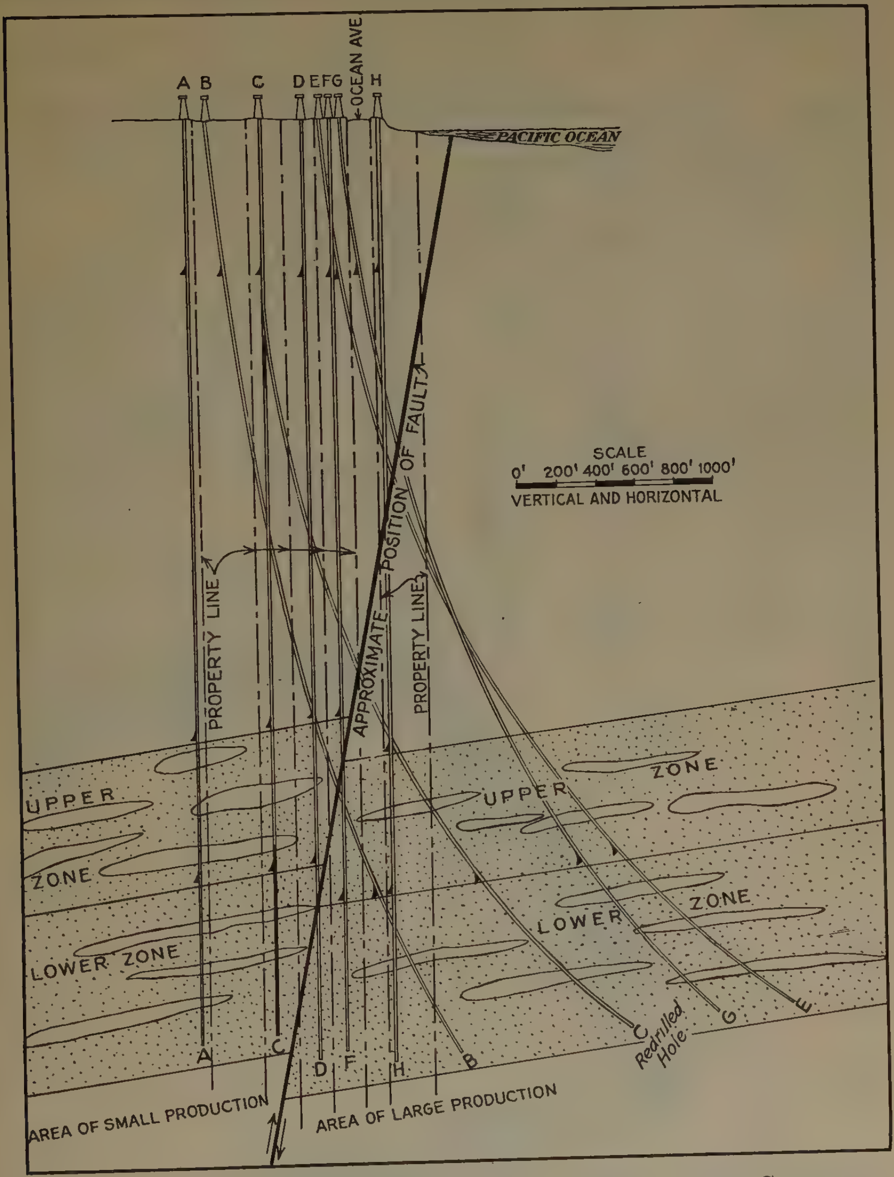

Fig. 7.—Directed drilling, Huntington Beach, Orange County, California.

phernalia. Like many other accomplishments, however, it is not so much the equipment as the ability to use it properly that is important. Efforts at directed drilling by novices have generally been dismal failures. It is to be assumed, of course, that more experienced men will become

available as the practice develops and that the details of procedure will gradually cease to be a trade secret, as they have been for the most part up to now.

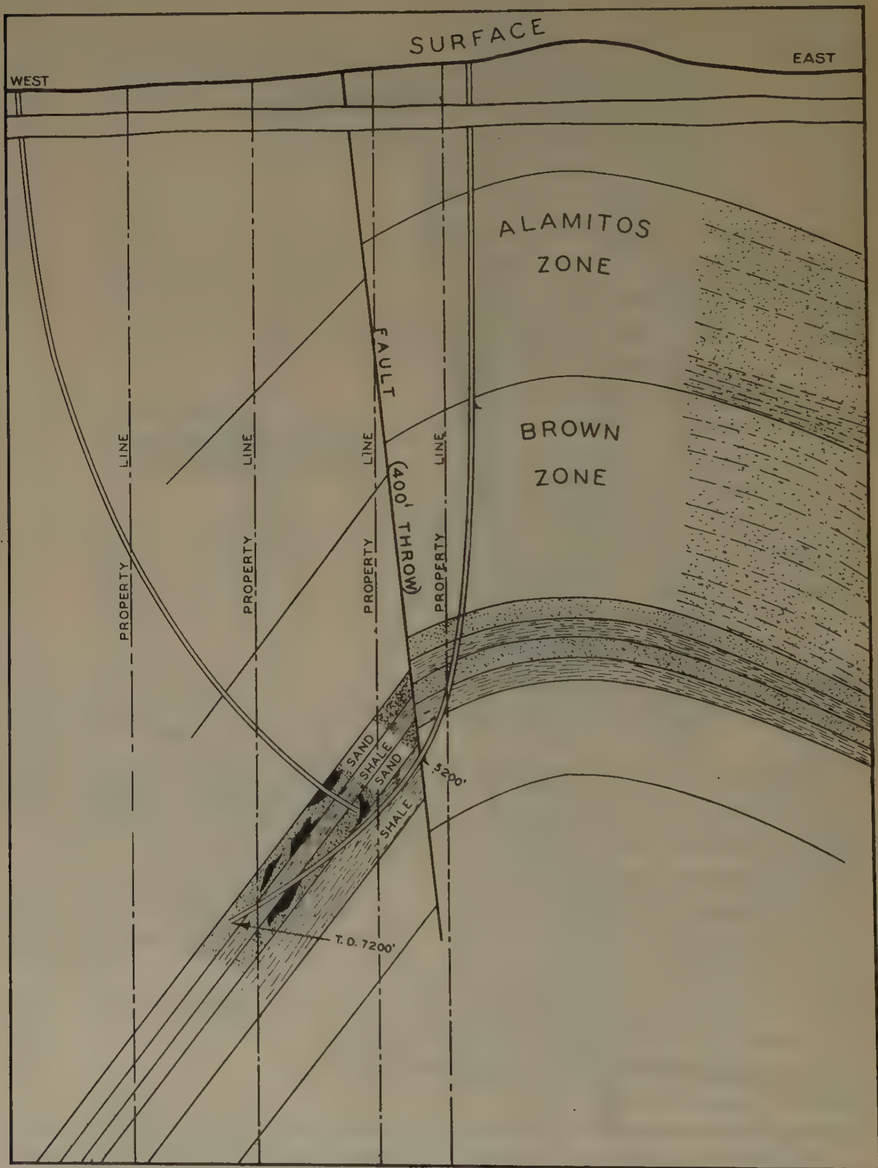

FIG. 8.—DIRECTED DRILLING, LONG BEACH FIELD, LOS ANGELES COUNTY, CALIFORNIA.

It is not unlikely that the directed drilling of oil wells under special conditions will continue, now that such drilling is so readily accomplished and if properly done does not cause production difficulties.

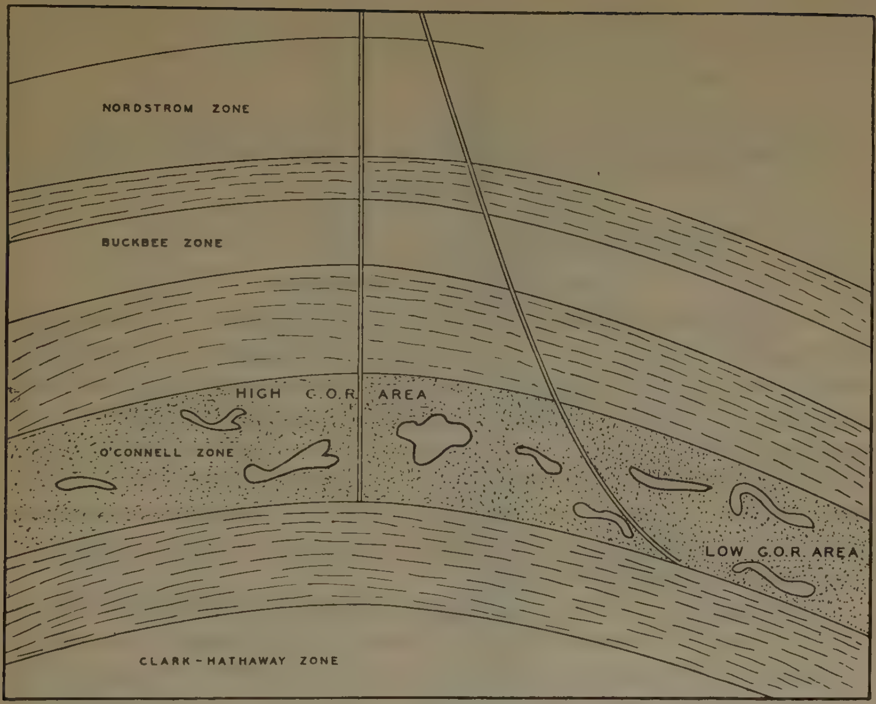

FIG. 9.—DIRECTED DRILLING IN SANTA FÉ SPRINGS FIELD, LOS ANGELES COUNTY, CALIFORNIA.

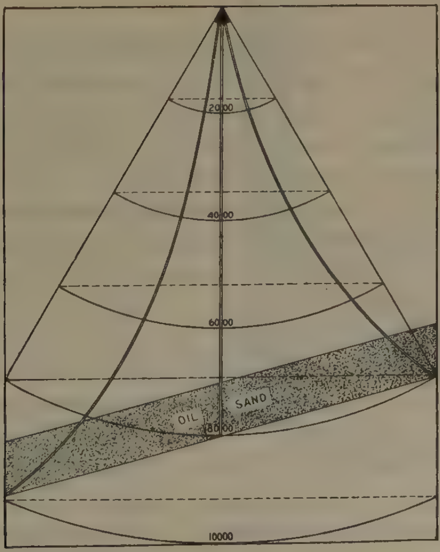

FIG. 10.—PRACTICAL RANGE OF DIRECTED DRILLING.

Instrument and Equipment for Recording Subsurface Pressures

By Ernest K. Parks* and C. W. Gibbs,* Taft, Calif.

(Los Angeles Meeting, September, 1933)

In 1929 the Standard Oil Company of California commenced the development of a device for obtaining temperatures and pressures in flowing and shut-in wells and of suitable running equipment for such a recorder. Although simple in principle, the recorder has required much experimental work in its development. The various problems have now been solved to such an extent that it is believed that the apparatus affords a sturdy and reliable means for obtaining information regarding depth pressures,—apparatus that may be turned over to a well gang for routine operation.

As an example of the rough usage the device will withstand a recent incident may be cited. Owing to failure of the lowering line at the conclusion of a run a recorder was dropped some 6300 ft. through 2½-in. tubing filled with gassy oil. The device was fished out undamaged and with the pressure record intact, although the instrument had been subjected to a pressure greater than 2300 lb. per sq. in. for some 24 hr. after impact at bottom.

Description of Recorder

The instrument is of the continuous recording loaded spring type (Fig. 1). Temperature is not recorded continuously but is obtained by maximum recording thermometers in an auxiliary thermometer well. The entire instrument assembly, from bottom of the recorder to top of the socket, is 6½ ft. long and weighs less than 25 lb. The maximum outside diameter of the recorder shell is 1¼ in., and all attachments need be no larger. This permits lowering the device inside 2-in. tubing.

The operating principle is simple. The well pressure acts upon a piston *A* resisted by the extension of spring *B*. The spring deflection is recorded by a stylus *C* upon paper within the recording drum *D*.

Springs.—To improve accuracy at lower maximum well pressures five interchangeable spring assemblies are used. These have maximum pressure ranges of from 250 to 5000 lb. per sq. in. Piston diameter is the same in all cases, and each spring is designed for a deflection of about 5 in. for maximum pressure loading. A complete spring assembly there-

* Petroleum Engineer, Standard Oil Company of California.

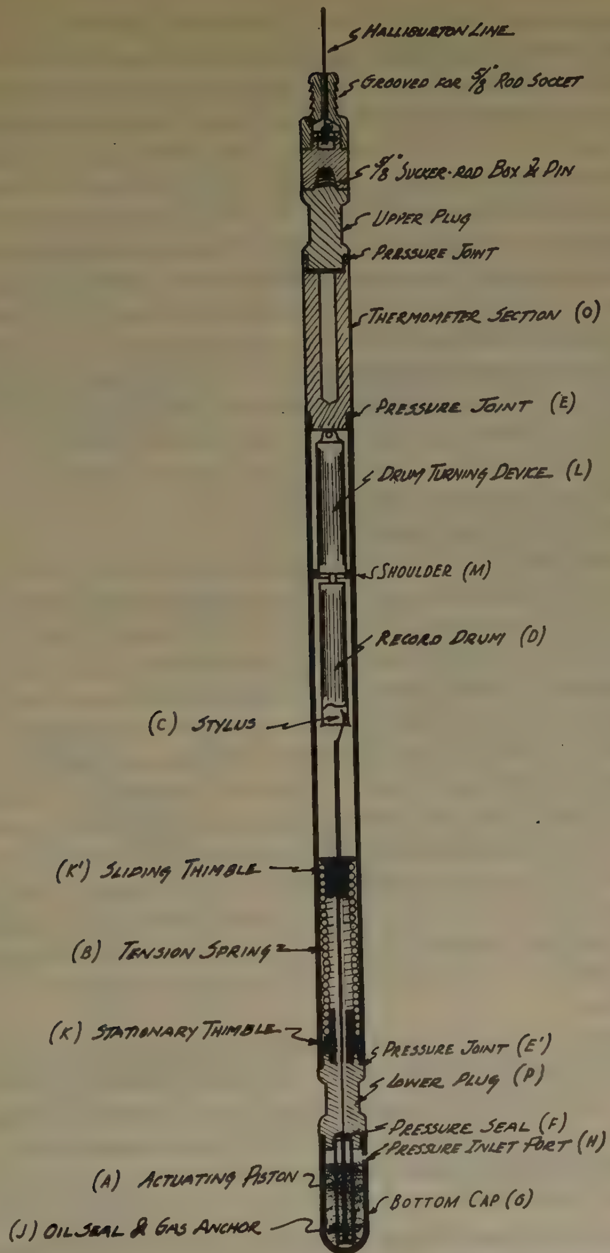

FIG. 1.—DIAGRAMMATIC SKETCH OF DEPTH-PRESSURE RECORDER.

fore consists of a tension spring B, stylus C, thimbles K and K' and actuating piston A, assembled as a unit in the lower plug P.

Pressure Joints and Seal.—Well pressure is excluded from the interior of the device by screwed and permanently gasketed joints E and E', and the seal F around the piston. The effectiveness of the pressure seal is increased by the oil-seal tube J. Bottom cap G is filled with clean oil to the level of pressure-inlet port H. Oil forced into tube J surrounds the piston with a clean oil seal when the well pressure is applied.

The pressure seal F consists of leather C-cup closely fitting the piston and placed in a machined recess in the lower plug. This type of seal has been effective in tests up to 5500 lb. per square inch. In practice there is usually a leak past the seal of from 2 to 3 cu. cm. of liquid per run. The piston is guided by a bronze bushing and the hardened sliding thimble K'. Friction due to cup leathers and guides is appreciable but is minimized by selection of materials used and careful polishing of the barrel. Experience has indicated that friction effects can be safely taken care of through periodic calibration.

Recording Portion.—Plain white metallic sensitized paper, upon which the brass stylus tip traces, is curved and placed inside the hollow record tube. This is turned by a device L. At present this is a so-called "thermal motor" but clockwork mechanism possessing somewhat greater flexibility is now under test. The thermal motor and record tube are assembled as a unit and rest upon shoulder M, being held in place by a lock nut at the top (not shown). The thermal motor is a double bimetallic helix, one end of which is secured to the motor case, the other to the drive shaft. By this means the motion of the helices under changes in temperature is transformed into rotation of the drum. It should, of course, be clear that it is not the temperature differential in the well itself that operates the motor, but rather the full differential between atmospheric and depth temperatures. To delay heat transfer and thus slow down the response of the helices, the thermal motor is insulated from the recorder case.

Temperature Record.—A maximum temperature for each run is obtained by the use of a regular armored maximum recording thermometer. For check purposes two are used. They are taped together and immersed in a mercury bath in the thermometer section O, which must also be pressure-tight. The recorded temperature is that at the lowest depth to which the recorder is lowered. The four or five minutes required for making a pressure observation is deemed sufficient to obtain the temperature record.

Socket.—On top of the thermometer section is a wire-line socket. Many types of sockets and methods of wire tying are in use, but a double lap around a ¼-in. pin followed by twisting the end around the wire has been found satisfactory. The figure is self-explanatory.

Fishing Tools.—A small set of jars may be run with the equipment, or may be useful in case a wire-line failure necessitates fishing. Slight alterations to a standard ⅝-in. sucker-rod socket makes this device a simple tool for picking up either the top of the recorder or the 1¼-in. diameter body.

Pressure Observations

A typical record is shown in Fig. 2. The zero line of atmospheric pressure is made prior to a run by giving the assembled recording device

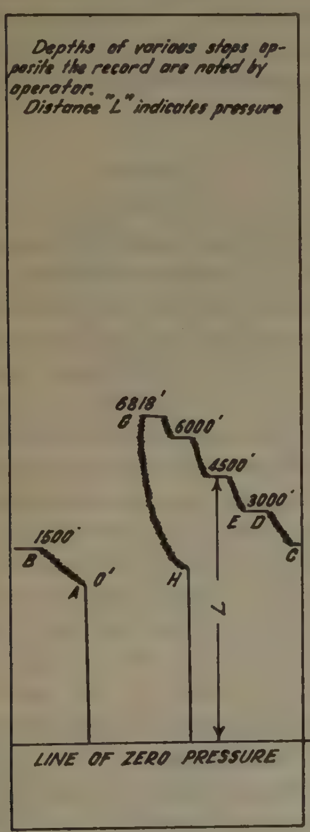

FIG. 2.—TRACING ON RECORD CARD OF OPERATING RUN.

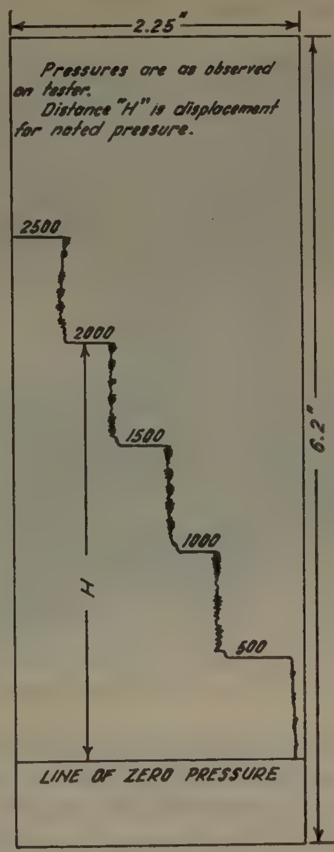

FIG. 3.—TRACING ON RECORD CARD OF CALIBRATION RUN.

one complete revolution before screwing on the cap. The instantaneous rise to A represents the sudden application of well-head pressure before the instrument is lowered into the well. The record AB represents the gradual increase in pressure as the instrument is lowered. The wide trace is caused by vibration of the stylus due to jarring of the instrument against the walls of the tubing. The horizontal line BC is a trace of the

stylus while the instrument is at rest at a desired depth, which is recorded in the operator's notes. When the stylus traveled from *B* to *C* it crossed the abutted edges of the record card within the recording drum. The line *CD* results from further lowering of the instrument and *DE* is a second observation. The line at the top of the graph is the final observation, and the trace *GH* is the path caused upon withdrawing the recorder. The vertical line from *H* to the zero line results from removal of well pressure and a return to atmospheric pressure. The perpendicular distance *L* from the zero line to any of the horizontal observation lines is a direct measure of the distance the spring has been stretched by the pressure load. The heights thus measured are converted to equivalent pressure readings by the use of calibration charts.

Fig. 4.—Calibration equipment.

Calibration

A dead weight tester is used for applying pressure for calibration. A typical calibration card is shown in Fig. 3. Since both well temperature and vibration affect friction, and hence spring deflection, calibration is carried on under simulated well-vibration conditions and at various temperatures. The calibration equipment is shown in Fig. 4. On the right is a dead-weight tester connected by copper tubing to the pressure-inlet port of the bottom cap. Pressure applied by the pressure screw of the tester is thus transmitted against the piston. The ring plates clamped around the recorder are to facilitate vibration of the instrument in the water bath and to protect the bottom pressure connection from being jarred loose. In the center of the figure is the container for holding the instrument in a water bath. This is a piece of 4-in. casing welded closed on the bottom, equipped with legs and with two thermometer wells. Vibration is accomplished by rapidly shaking the instrument in the container from side to side. Calibration consists of a record at five or six intervals over the range of the spring repeated at several temperatures. Since in each case the pressures are recorded at a constant temperature the recorder drum must be rotated by hand. The results are plotted on a graph as in Fig. 5. As an example of the use of the graph, suppose that a distance

L on Fig. 2 is 2 in. and the temperature at that depth is measured or calculated as 180°. Assuming that the graph of Fig. 5 is for the same spring as is used in the well, the value of the 2-in. displacement at 180° is seen from the chart to be 1220 lb. per square inch.

It is obvious that the temperature at which the well pressure is observed must be known. This is approximated by having a suitable temperature traverse for the well concerned. Frequently wells in the same field are so nearly alike in this respect that separate traverses need

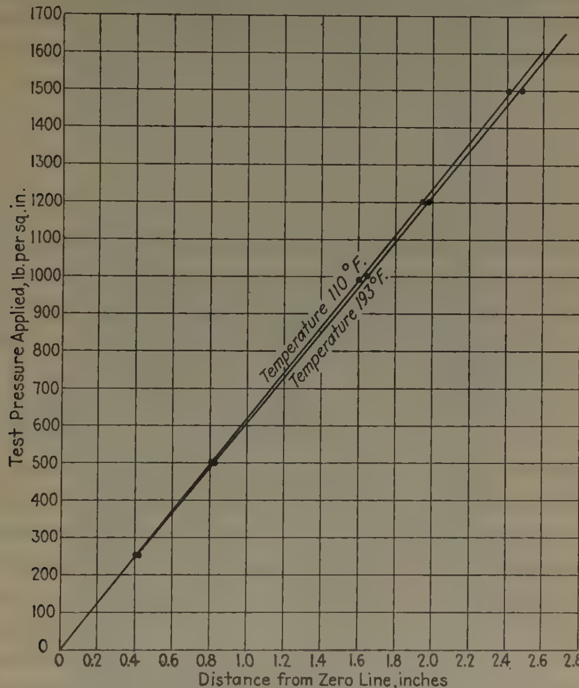

FIG. 5.—PORTION OF CALIBRATION CHART.

not be made. In these instances it has been noted that temperature increases quite uniformly with depth. Thus, knowing the surface temperature and that at a certain depth from the maximum thermometer, a straight line is drawn between the two points and the intermediate temperatures can thus be estimated.

Accuracy

Check runs in the same well have been found to agree within less than one per cent of the maximum spring range. Runs made in columns of known density—such as water—have shown equally good results. As stated before, the absolute accuracy of the equipment depends largely

upon the accuracy of the calibration. Periodic calibrations indicate but slight changes from time to time owing to careful spring design, good manufacturing practice and thorough inspection.

Brief mention may be made of the possible error in readings caused by introducing the recorder in the flowing stream. Doubtless the device interferes somewhat with normal flow and hence alters the pressure indications, particularly where the tubing is small and the velocity high. Since, however, the weight of the recorder is only some 20 lb. per sq. in. of cross-sectional area, it is believed that where the recorder will enter the stream and fall against upward flow, the maximum error due to restriction is less than this figure. In static pressure readings no similar error, of course, is introduced by the instrument.

Operating Equipment

The Line.—The recorder is run on a single 10,000-ft. length of wire of 0.064-in. diameter with an ultimate strength of about 800 lb. The wire seems to be very stiff but with care to prevent kinking it has been found quite suitable. The line is an easily obtained commercial product.

The Hoist.—The hoist may be one of several varieties. Fig. 6 illustrates a shop-made hoist mounted upon a steel beam bolted to the rear end of an automobile. The power take-off is supplied by a V-belt, which is represented by a rope in the photograph. The geared ring on the left flange is for the purpose of allowing the reel to be turned by a hand crank. At the conclusion of a run the jack hoist is unscrewed and removed from the slotted base, the belt is removed and the hoist is slid to the right, and secured to the I-beam by a bolt. The use of this hoist involves the jacking up of a rear wheel of the car and necessitates an operator at the wheel and also at the brake. An improved but more expensive arrangement is shown in Figs. 7 and 8. The hoist is driven by a V-belt connected to a pulley driven by a power take-off from the truck transmission. The hoist, frame and power take-off are parts of a commercially manufactured unit.

The Lubricator.—The principal features of the lubricator assembly are the 2-in. lubricator body, flange, bleeder valve, stuffing box, hoist bracket and sheave. A longer lubricator must be employed if jars are run with the pressure recorder. In fields where pressure runs are routine, a valve and half flange remain on top of the Christmas tree as permanent well equipment. The lubricator is hoisted into position at the top of the tree by a rope that passes over a block hung on a small cable stretched diagonally across the derrick. The cable and tackle are also permanent fixtures.

Floor Sheave.—In Fig. 9 the man on the left holds the recorder and the special wrench used to prevent deformation of the recorder case. The


6
7
8

FIGS. 6–8.—SHOP-MADE HOIST AT TOP, WITH IMPROVED BUT MORE EXPENSIVE HOIST BELOW

man on the right holds the lubricator and a ratchet wrench used for opening and closing the gate valve just below the lubricator flange. On the floor at the left is bolted the floor sheave under which the wire line from the truck passes to the lubricator sheave. This sheave is protected by a slotted guard and is mounted on a swivel bearing.

Operation

A full crew for deep, high-pressure well tests consists of a gang pusher to operate the hoist and two roustabouts. On lower pressure or shallower wells two men have satisfactorily operated the automobile wheel-driven hoist and equipment first described. The time required for a run varies with the type of test made as well as with the distance from headquarters to well. A simple pressure traverse of a 7000 to 8000-ft. well requires from 45 min. to an hour for the actual run. Rigging up, pulling out and traveling time increase the total time required for a run. On the average, however, a schedule of simple pressure observations on at least two such wells per day can be maintained.

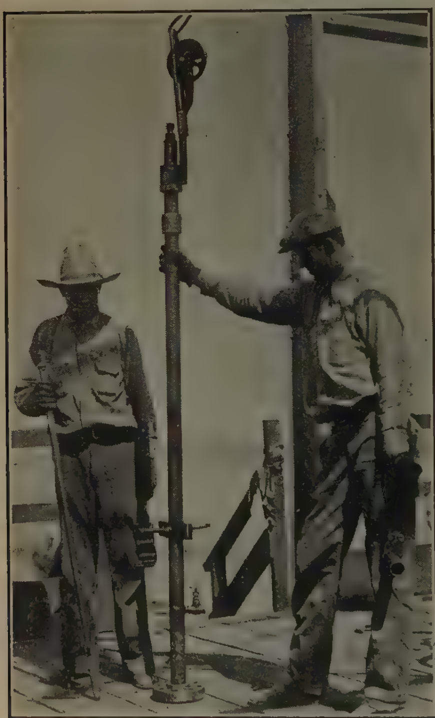

Fig. 9.—Recorder, lubricator and wrenches. Floor sheave at left.

A typical set-up is shown in Fig. 10. Fig. 11 shows two members of a crew making up a pressure joint just prior to a run.

The speed with which the recorder is lowered in a well depends somewhat upon the flow conditions. In shut-in wells, and in those wherein the resistance of the rising column is not too great to interfere, lowering speeds of 600 to 1000 ft. per minute are employed. Normal hoisting speed is 600 ft. per minute. Limiting well flow and lowering speed relations can hardly be given definitely. The speed at which the device will drop in a flowing well depends upon the density and velocity of the rising column, which in turn depend not only on tubing diameter and flow rate, but also upon pressure, temperature, degree of heading or slugging, gas-oil ratio, etc. Occasionally flow conditions have been encountered against which even additional weighting of the recorder would not permit lowering

into the well. Although not necessarily representing limiting cases, the

FIG. 10.—TYPICAL SET-UP, WITH HOIST ON TRUCK AT LEFT.

illustrations in Table 1 of rates, pressures, etc., against which the instrument has been lowered successfully may be of interest.

FIG. 11.—MAKING UP A PRESSURE JOINT.

USES TO WHICH INSTRUMENT HAS BEEN PUT

Shut-in Depth Pressures.—Pressures at various depths have been taken periodically in shut-in wells. Where the well is normally producing the shut-in traverse is made after an arbitrary shut-in period of 24 hr. Thus from time to time is obtained a measure of the decline in reservoir pressure in the area immediately surrounding a well. In certain instances there have been opportunities to study pressure variation in wells continuously shut in over a period of months. Such readings give information on the larger question of general pressure decline in the reservoir.

Pressure "build-up" data have been obtained in a number of instances. Such data are obtained by recording at successive short intervals of time the depth-pressure changes following the shutting in of a producing well. These data bear upon permeability of the producing formation.

TABLE 1.—*Conditions Against Which Instrument Has Been Lowered Successfully*

	Barrels per Day	Gas-oil Ratio	Surface Back-pressure, Lb.
4¾-in. flow string........	4,900	700	600
	1,700	17,000	1,100
3-in. tubing.............	2,600	2,700	650
	1,300	1,000	260
	650	19,000	1,420
2½-in. tubing............	2,400	800	250

Flowing Depth Pressures.—Traverses of flowing wells have been made and used in the study of efficient flow-string design, friction, and head losses, etc. The indicated drop from shut-in pressure while flowing at various rates has been used in the preliminary study of well spacing, drainage, permeability of formations, and so forth.

Miscellaneous.—The recorder has been useful in indicating mud bridging in the lower portion of wells in addition to locating the height of water or oil column present in certain shut-in wells. Other specific data of interest have been obtained, such as proof that an upper sand had a higher pressure than one directly underlying it in a recent test. Such information has a distinct value in guiding production practices.

Doubtless each engineer could enumerate a number of special studies that could be made of conditions peculiar to his own situation. It is not believed that depth-pressure study alone represents the solution to all development and production problems. It is indicated, nevertheless, that reasonably reliable basic data can be obtained without hazard to wells and at not too great expense, and that such data have possibilities of being helpful in modern development and production practice.

Formation Testers

By Frank E. O'Neill,* Los Angeles, Calif.

(Los Angeles Meeting, September, 1933)

The formation tester, as the name implies, is a tool built for testing the contents of sands encountered in drilling wells without actually cementing casing on the sand.

The tester was developed in the Mid-Continent and has been in use commercially there since about 1926. However, some two dozen patents have been issued on formation testers dating back to the seventies. The method apparently was an outgrowth of the old Mother Hubbard grain or bean packer, used around casing before the days of cementing casing. These packers were also seated in a tapered hole and if the formation tested was not satisfactory the casing was pulled loose and the hole taken down to another formation. A great deal of experimental work has been done in its development, and as a result of this work the formation tester became an accepted integral part of the petroleum development in California.

The formation tester was introduced into California some three years ago by M. O. Johnston. Months of discouraging and expensive work followed its introduction into this state, but one organization after another tried the tool and its use is now fairly general. Shortly after Johnston began testing in California, the Halliburton tester was also introduced into the state and now another tool is being introduced, the Shaffer-Boles tester.

Principle and Operation of Testers

The principle employed in all formation testers is that of packing off the fluid in the hole above the formation to be tested and thereby preventing it from having access to the testing tool. This permits the fluid contained in the given formation to have unrestricted access to the tool. It is accomplished by running the tool and packer on the bottom of the drill pipe; the valves in the tool being closed while going into the hole to prevent fluid from entering the drill pipe. The packer is then seated at the desired point, trapping the drilling fluid above it. When this has been done, the valves in the tool are opened and the fluid from the formation is allowed to enter the empty pipe through the tool. If the

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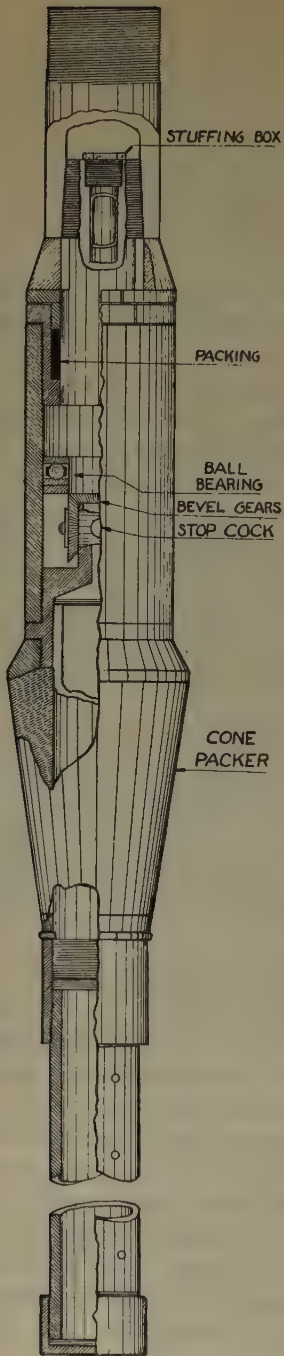

Fig. 1.

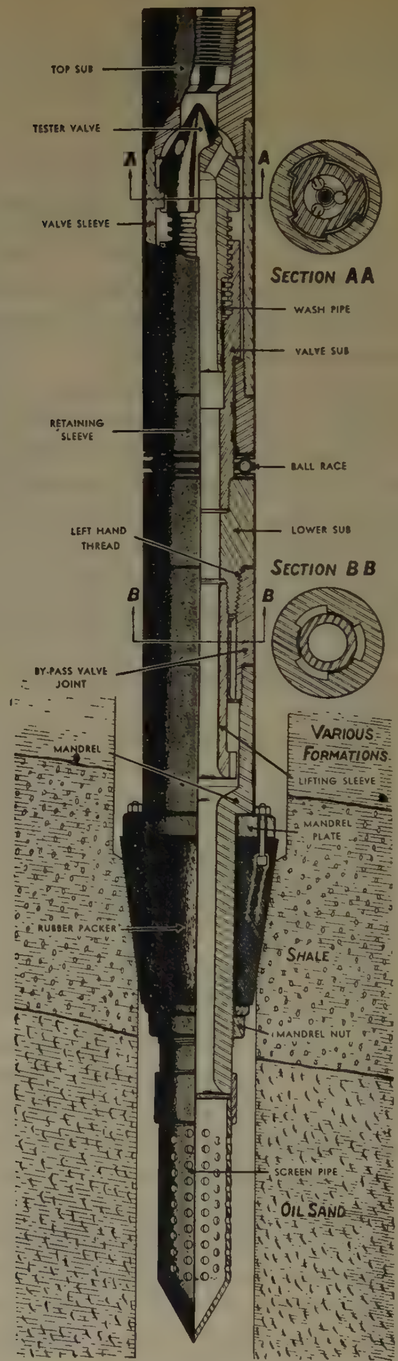

Fig. 2.

Fig. 1.—Halliburton formation tester with cone type of packer.
Fig. 2.—Shaffer-Boles formation tester.

pipe is run entirely empty, this process opens the formation being tested to atmospheric pressure. In other words, it is bailed dry in an instant.

If it is not considered wise to open the particular formation to atmosphere, any desired back-pressure can be maintained upon the formation by running fluid into the drill pipe before the valve is opened.

A wet cloth placed over the top of the open drill pipe normally offers adequate indication of the progress of the flow, as fluid entering the lower part of the pipe exhausts the air, contained in the pipe, at the surface.

If the fluid packed off between the drill pipe and the hole does not fall when the tool is opened, it is reasonably certain that the packer is holding and that whatever fluid comes into the drill pipe has come from below the packer. If, on the other hand, the fluid that is packed off falls when the tool is opened, it is certain indication that the packer is not holding and that the fluid entering the drill pipe is coming from above the packer. In other words, if the packer does not hold, the fluid behind the drill pipe will equalize into the drill pipe if the valve is left open. When this occurs, the valve is closed immediately, to prevent the rush of fluid around the packer and into the drill pipe. There is nothing on a test more important than to watch the fluid between the drill pipe and the hole when the tool is opened.

Types of Testers

There are two general types of testers: (1) those operated by rotating the drill pipe (Halliburton and Shaffer-Boles); (2) those operated by raising or lowering the drill pipe and by use of a go-devil dropped through the drill pipe (Johnston).

The valve in the Halliburton tester (Fig. 1) is opened and closed by means of beveled gears contained in the tool, and operated by rotating the drill pipe. The valve in the Shaffer-Boles tester (Fig. 2) is opened and closed by means of screw threads similar to the Shaffer bean and is operated by rotating the drill pipe. The valve in this tester is closed by reversing the direction of rotation.

The Johnston tester (Fig. 3) is operated by raising and lowering the drill pipe. It has two valves. The main valve is controlled by a heavy spring, like the springs on the trucks of a box car. The valve is opened, after the packer is seated, by giving the pipe weight and is snapped shut by the spring whenever the pipe is picked up enough to relieve the weight. The tension on this spring is set according to the depth of the test. The second valve, the trip valve, is opened by a go-devil dropped through the drill pipe when the test is ready to proceed. The go-devil is recovered when the tool is pulled from the hole.

While formation testers were designed primarily for use in open holes, they have been adapted successfully in California to water shut-off tests on casing and have been accepted by the California State Division of Oil

and Gas as desirable for such use. The adaptation of the formation tester to this new use was accomplished by Johnston, made possible through the cooperation of the Standard Oil Company of California and other enterprising operators. During the past 18 months there have been well over one hundred successful shut-off tests of the formation tester run for the state.

The String of Tools

The tools employed in making a test with the formation tester include the testing tool, the equalizing valve, the packer and the anchor.

The testing tool, as developed in the Mid-Continent and introduced into California, was already equipped so that fluid could be circulated through it by means of the pumps. The California work presented a new problem to the testing business, that of depth. Great difficulty was encountered in lifting a packer of any kind off the seat in the deep holes. The extremely hard pull required to unseat the packer endangered the drill pipe and the well and made the operators skeptical about using the tool. To eliminate this danger, Johnston designed and built an equalizing valve to be placed between the tool and the packer, which solved the difficulty and is now used regularly in one form or another as part of all of the testing tools in California. The function of the valve is to equalize the pressure above and below the packer when the test is completed. When the tool has been closed after the test, the equalizing valve is opened and through this valve the fluid that has been trapped above the packer is turned down through the packer and discharged against the formation that has been producing, thereby replacing the fluid taken out from below the packer and relieving the partial vacuum or reduced pressure caused by the removal of fluid. With the pressure equalized above and below the packer, only a slight pull is needed to lift the packer from the seat. The valve also serves another important need; when the equalizing valve is opened, it turns the mud from above the packer down on to the producing formation and instantly kills the well. This mud has not been exposed to the flow of the well through the tool and is not gas-cut or shot through with oil. It is clean, fresh mud, and it is discharged at the bottom of the pipe, which is the most effective place for killing a well.

Another difficulty arose in the California work. No casing tests had been run in the Mid-Continent, and it was necessary to develop a safe and effective packer for casing tests. The packers in use in production work were found to be inadequate. They had been designed to run through a relatively thin fluid, after a well had been cleaned up for production. It was discovered that running such a packer through heavy mud, at a greater speed than tubing is usually run, caused the packer rings to expand from fluid pressure while going into the hole and

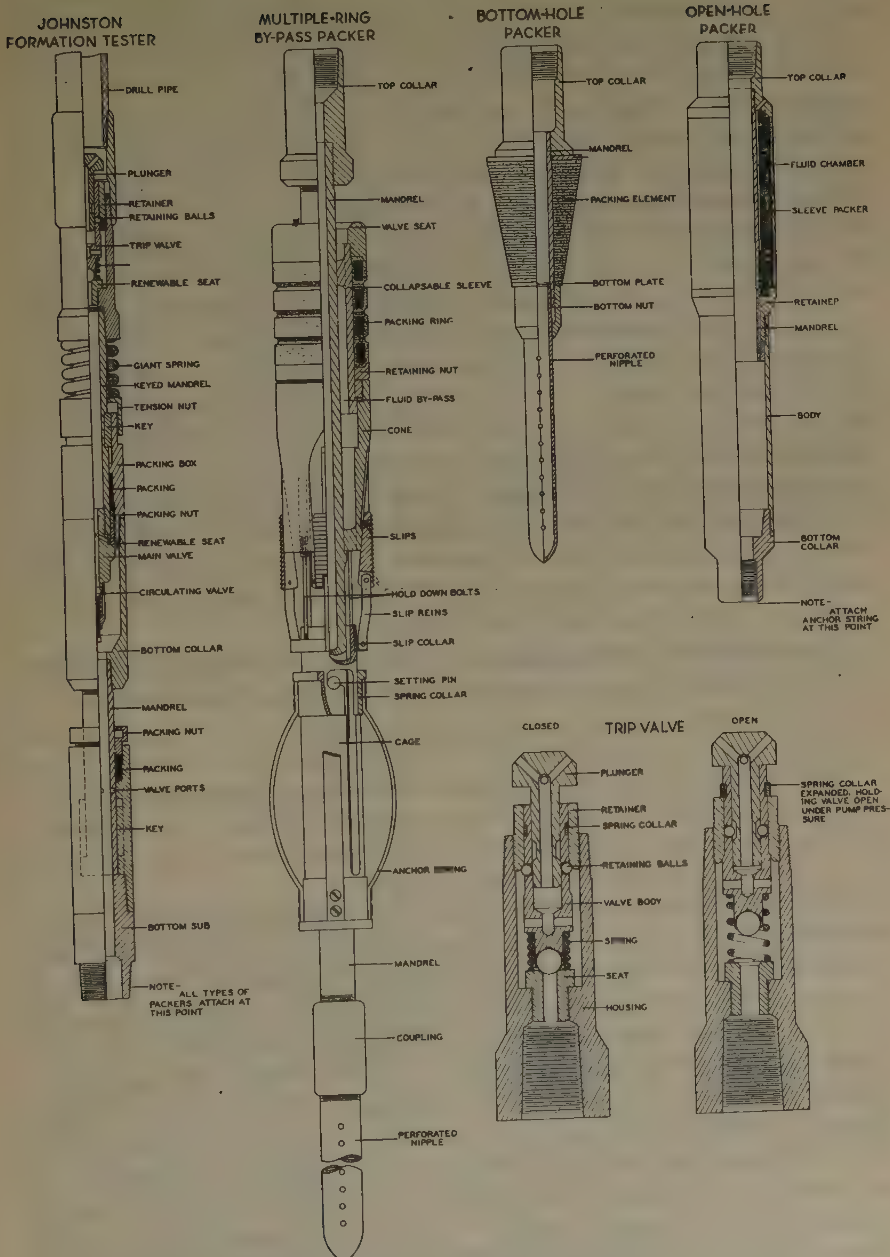

FIG. 3.—JOHNSTON FORMATION TESTER, PACKERS AND TRIP VALVE.

thereby made them useless by the time they reached bottom, or caused the packer to set before bottom was reached. Johnston met this difficulty by placing a bypass through the packer, which would permit the mud to pass upward through the packer while going into the hole and seal off with a valve when the packer was seated. After the original bypass was designed, the opening was found to be too small, so he designed another packer with a sleeve inside the rings and a larger bypass. This work successfully eliminated the ring troubles.

The long slip reins on the casing packer were difficult to keep in shape and frequently broke, leaving a slip in the hole. They also caught whatever debris there was in the mud from drilling out the cement plugs. This was corrected by using short reins and dovetailed slips. Still another difficulty was encountered and overcome in obtaining slips that would take the necessary weight and would hold in the hard casing, particularly the grade D pipe used in Kettleman Hills. A casing packer can be designed so that it will pack off every time, but the restraint that is constantly placed upon the designer is the necessity for having the packer so constructed that it will not be difficult to get out of the hole. The wrong construction can cause a packer to stick to the degree of danger. Today the packer used for casing tests in California packs off successfully 95 per cent of the time and is safe to run.

The anchor used on the bottom of the string of testing tools is merely a short perforated nipple, closed on the bottom to serve as a screen.

Tests Made in Open Hole

The same testing tool is used for testing in the open hole as for use in casing but the packer employed in each case is different. For open-hole work, there are two types of packers; the wall packer or straight-hole packer and the shoulder or bottom-hole packer.

The wall packer is used when packing off against the walls of the hole where there is no pilot hole ahead for a shoulder. It is a rubber sleeve mounted on a mandrel that can be collapsed vertically. To the lower support for this sleeve is attached sufficient pipe, containing some perforations, to reach from the point of packing off to the bottom of the hole. When the weight of the drill pipe is let down upon this supporting anchor, the sleeve is compressed and squeezed outward against the walls of the hole, thereby packing off. This type of packer can be used effectively in holes of small diameter, 7 in. or less at depths up to 5000 ft. In holes of larger diameter, or deep holes, it is difficult if not impossible to pack off with this kind of packer. Under such conditions, the rubber sleeve will usually be forced over the lower support and down upon the anchor when the tool is opened, resulting in failure to pack off. Even though this method should pack-off successfully, there is danger of freezing the long anchor. A left-hand thread is run ordinarily at the

top of the anchor to meet such emergencies, and when the anchor freezes it is necessary to back off and wash over in order to recover it.

The straight-hole method of testing is not recommended. The best method of packing off in formation is by means of the shoulder or bottom-hole packer, in which there is relatively little danger. A pilot hole is kept ahead of the big hole, leaving a shoulder of several inches between the two. The packer rests upon the shoulder at the top of the pilot hole and packs off by weight rather than by expansion. The packer for this work is made of disks of canvas or rubber belting slipped over a rigid mandrel and drawn tightly together by means of a large nut on the bottom. A short perforated anchor is attached to the bottom of the packer purely as a strainer to keep large particles of formation from entering the tool and plugging up the small openings in the tool. If this packer sticks, the mandrel can be pulled through the belting disks, leaving only the belting in the hole, which can be pumped out. Such packers have been run successfully to depths below 9000 ft. This kind of packer requires only enough foresight to carry a shoulder in the hole when the danger zone is reached, and it offers the operator the greatest possible security.

Preparation of Shoulder

A few important points need to be considered in preparing a shoulder in a well for future testing: (1) A pilot hole should be carried ahead; (2) the taper on the shoulder should be carefully made; (3) the taper should not be cut on the shoulder until the last run before the tool goes in; (4) the testing company should be consulted concerning the details.

Operation of Packers

Formation packers require a certain amount of skill in their operation, which is born solely of experience. When formation tests are placed in the hands of experienced men, the percentage of successful runs is high. On shoulder packers probably better than 80 per cent of the runs are successful if entrusted to thoroughly seasoned well men.

The shoulder packer will pack off in firm sand about as well as it will in shale. The formation should be examined in the cores where the packer seat is to be made. If the formation is badly fractured it is next to impossible to make any kind of packer hold. Hard shells form splendid seats for packing off if they have not been fractured. In some areas the shale, although it appears to be very firm, will not hold a formation packer, and it is necessary to go to the top of the sand in order to get a satisfactory seal. The testing companies can offer the operator, in some cases, the benefit of experience that will be of assistance to them in choosing a suitable seat for packing off.

Some of the difficulty of packing off, where the dips are steep or where the formation is slightly fractured, can be eliminated by the use of a canvas apron on the packer. The apron is made 4 or 5 ft. square. A hole is cut in the center and the apron slipped over the mandrel before the belting disks are put on. In the event of a small leak, the fluid sucks the canvas down into the hole and plugs it off.

Formation packers are generally allowed to set from 25 to 35 min. This depends, however, upon the action of the well. If the well is exceptionally active, 2 or 3 min. may be sufficient. Packers have been allowed to set 40 min., but 35 min. is considered ample to give an indication of what may be expected from the sand. If the well is going to flow, it will show this fact rather quickly. If it is salt water, its presence will be determined in a short time. If the sand is clean but contains very little gas or has a low fluid level, the results may appear to be indeterminate but the absence of salt water will give some clue as to its possibilities.

Tests Made in Casing

When running a formation tester in casing, a hook wall packer is substituted for the formation packer. The packer is tripped by a turn to the left and is then seated 6 to 12 ft. above the shoe. The action of the tool is the same as in a formation test but the time that the tool is allowed to set is not a matter of importance. Wells have been flowed through a testing tool in casing for several days, killed when the test was completed, and the tool pulled from the hole without difficulty.

When a shut-off test is run with the testing tool, the operator not only saves a great deal of time but gets a more positive test than can be had by bailing or swabbing, because the amount of hydrostatic head left upon the shoe can be regulated without danger to the casing. If it is desirable to bail it dry with the tool, this can be done safely. It cannot be done, however, by a bailer or swab on a deep well. The use of the testing tool eliminates the strain set up in the casing by continually striking the fluid with the bailer.

Each time that the bailer is run into the hole, it strikes the fluid with considerable force and places a form of water hammer upon the casing. There is a tendency for the casing to expand under this blow. The bailer is then submerged and pulled from the fluid, dragging the fluid upward and setting up in the casing a tendency to contract. The bailer then leaves the fluid and the fluid drops back again, causing a slight hammer effect. This continual breathing of the casing is kept up as long as bailing is continued and is thought by the writer to be responsible for many wet jobs on bailing tests. In testing casing with the tool, the casing is insulated from vibrations with a column of fluid that is stationary. At any rate, there has been a smaller percentage of wet jobs on casing with the tool than has been found with bailing tests.

Again, when a well is bailed the strain is placed on the upper part of the casing where there is no cement to support it, the tool places the strain on the bottom part of the casing, where it is thoroughly cemented.

The time required for the average shut-off test with the tool is 6 hr. against approximately 48 hr. with the bailer or swab.

Formations below the casing may be tested in stages by use of the testing tool. After the shut-off test has been made, the tool can be used for a quick test of each 50 or 100 ft. of new hole by using a casing packer.

Heaving Formations

Some areas have a tendency to heave or bridge below the tool when the valves are opened. This may occur in either a casing or formation test. The result of such a bridge is the same as it would be if the bridge were thrown during a bailing test. It may prevent the fluid from reaching the tool, thereby permitting only a slight rise in the drill pipe. When this occurs, it is overcome by placing a bean of any desired size in the tool and using a valve at the surface that is kept closed until the valves in the tool are open, making it necessary for the fluid to enter the drill pipe against an air cushion. The surface valve is then slightly opened and the air bled out slowly as the fluid rises in the drill pipe. In some areas where the pressure is high, the drill pipe may be run in partly filled with mud, to cushion the entry of fluid and prevent heaving.

A Theoretical Analysis of Water-flooding Networks*

By M. Muskat† and R. D. Wyckoff,† Pittsburgh, Pa.

(Los Angeles Meeting, September, and Dallas Meeting, October, 1933)

The general problem of the simultaneous movement of water and oil in a connected sand is of considerable practical interest from two points of view. First, there is the situation usually described as "edge-water encroachment." Here the water in the sands contiguous to and flanking the oil sand begins to enter the latter as the oil is removed and the reservoir pressure declines. The physical questions involved concern an understanding of the mechanism of the advance of the water and its control, so as to aid the oil recovery rather than to hinder it. In so far as the entry of the water into the oil sand means at least the partial replacement of the oil from the region of the encroachment by the advancing water, it is quite appropriate to consider this type of situation as one of *natural* water-flooding.

For the present discussion, however, we are primarily interested in the problem of *artificial* flooding. Here the water is deliberately injected into the oil sand with the intention of displacing the oil and removing it through prearranged output wells. For the practical development of such a procedure rather large areas are included in the flooding program and the injection and output wells are arranged in regular patterns or networks, which are felt to be most favorable for a high oil recovery. Although remarkable success has already been obtained in such flooding programs, especially in the Bradford field of Pennsylvania, essentially by the application of the lessons of practical engineering experience, a more thorough physical analysis of the problem appeared to offer promise of leading to results of some interest and value.

Another phase of the problem, which stimulated both the experimental and mathematical analysis, is that it is susceptible in large measure to empirical field tests. It is in itself but an example and illustration of the general theory of the flow of dead (gas-free) liquids through porous media, in which the authors have been interested for the last several years. From the point of view of its applicability to actual petroleum technology problems, however, water-flooding is a particularly favorable

* This paper is a summary of A.I.M.E. *Technical Publication* 507 (1933). It gives the results on which the authors' conclusions were based, presented without the mathematical details that were included in the longer paper.

† Gulf Research and Development Corporation.

example. In fact, it is hoped that it will be possible to make empirical tests, by those engaged in flooding programs, of the more practical results of the theoretical analysis.

Although it is felt that the theory of flooding developed here has a direct applicability to the practical field problem, the limitations and assumptions of the theory must be kept in mind, as follows:

1. The assumption of steady state conditions. This means that the theory does not apply until the state has been reached in which the fluid output equals the fluid input; that is, until after the passage of the initial transients during which the residual gas in the sand is being compressed and the input volume exceeds the fluid output.

2. The systems are two dimensional. This implies that the sands are relatively thin and that the water-oil interface is a sharp vertical boundary. The effect of gravity in inclining this boundary would lead to a somewhat earlier arrival of the water at the output wells than predicted by the theory.

3. Neglect of the difference in viscosity between the water and oil. This is perhaps the most serious of the approximations, although it is an absolutely necessary approximation if the analysis is to be carried through at all by other than extremely tedious numerical and graphical means. The effects, however, of the viscosity difference in the practical problem are readily seen qualitatively. Thus, the lower viscosity of the advancing water will accelerate the "cusping" or "fingering" of the interface and hence lead to lower efficiencies—less complete flooding—than predicted by the theory, although the magnitudes of this effect will be small, since it will be pronounced only where the "fingering" would be marked even if there were no viscosity difference. The resistance of the networks, on the other hand, may be appreciably decreased by the lower viscosity of the water. Although the magnitude of this decrease can be closely estimated, it is not considered further in this discussion.

Somewhat analogous to the effect due to differences in viscosity is the so-called "bypassing" tendency, which is due to the presence in the sand of two immiscible liquids, water and oil. Thus there is present in the flooding process the unsolved problem of the flow of mixtures. Qualitatively, it may be said that the bypassing tendency of the driving fluid in such a mixture is recognized in the statement that only a partial replacement of the oil takes place in the region of water encroachment. Hence, as a first approximation, it is reasonable to conclude that the major effect of the presence of a mixture of fluids in the sand is to speed up the encroachment—as if the total volume of free pore space involved in the flooding process were decreased by an amount equal to the volume of the oil retained.

Returning now to the treatment of the flooding problem, it is convenient to distinguish between and discuss separately the efficiency of

a flood, which is the percentage of the flooded area that is swept out by the encroaching water before water actually reaches the output wells—and which is a measure of the tendency of the water to "bypass" the oil

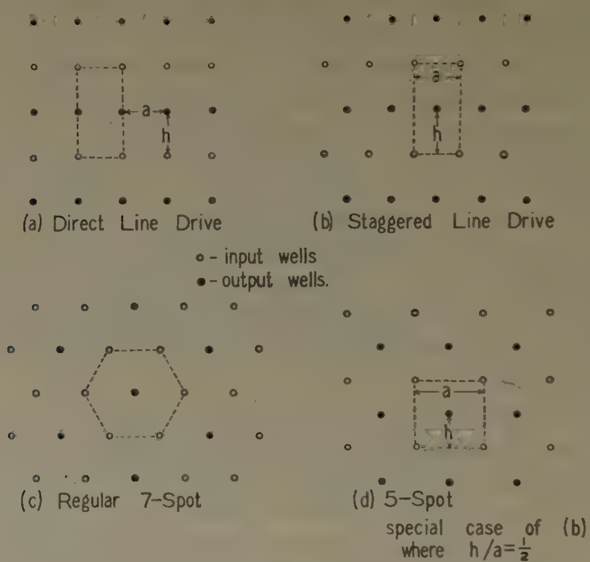

FIG. 1.—DIAGRAM OF TYPICAL FLOODING NETWORKS.

due to the nature of the pressure distribution—and the "conductivity" of the flood, which is the steady state production capacity of the net-

FIG. 2.—FLOODING HISTORY OF A DIRECT LINE DRIVE.

work per unit pressure differential between the input and output wells. The reciprocal of the conductivity may be termed the "resistance" of the flood.

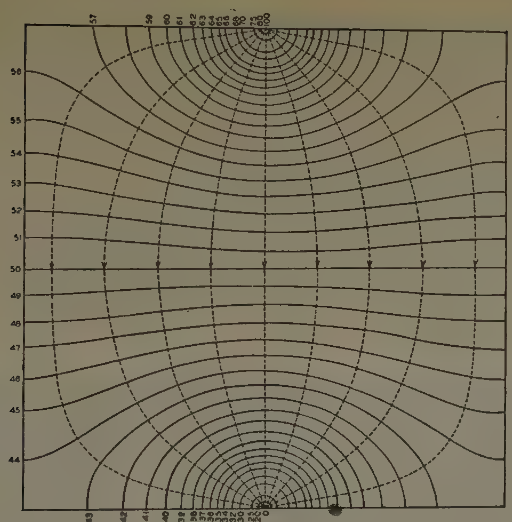

FIG. 3.—PRESSURE DISTRIBUTION IN A DIRECT LINE DRIVE.

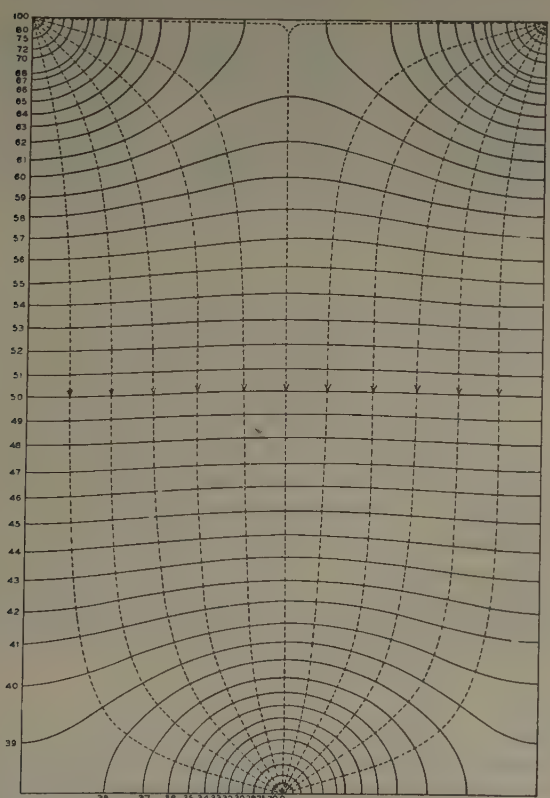

FIG. 4.—PRESSURE DISTRIBUTION IN A STAGGERED LINE DRIVE.

Fig. 1 shows schematically the several types of flooding network considered in this discussion. A very simple and graphic way of studying the flooding efficiency of a network as defined above is by the use of an electrolytic model of the flood.[1] For a clear understanding of these models, however, it is necessary to consider at the same time the pressure distributions in the flooding systems.

Thus in Fig. 2 is shown the photographic history of the direct line-drive flood with a flooding efficiency of 57 per cent. The very symmetrical pressure distribution in this network is given in Fig. 3. This distribution and those in Figs. 4 and 6 were obtained by means of electrical current conduction models.

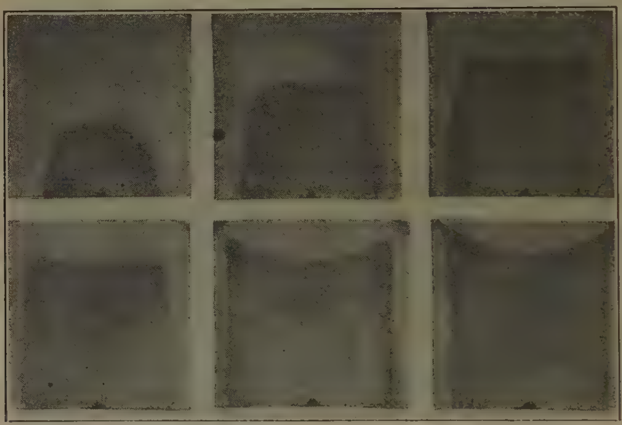

FIG. 5.—FLOODING HISTORY OF A STAGGERED LINE DRIVE.

In contrast to this case the pressure distribution for the staggered line drive in which the input and output lines are mutually shifted parallel to themselves by one-half of the well spacing may be considered (Fig. 4). Here the equipressure lines split so as to encircle the two corner wells. As the fluid will tend to divide and flow toward the wells, the front evidently will undergo a preliminary broadening before finally fingering in symmetrically into the two corner wells. This tendency to spread out the flood instead of concentrating it along the single line of centers, as in the direct line flood, will obviously lead to a greater areal flooding and hence higher efficiency. Fig. 5, showing the electrolytic model photograph, clearly corroborates all these deductions, the last photograph showing a flooded area (or efficiency) of 77 per cent in contrast to the 57 per cent of the direct line-drive flood.[2]

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[1] R. D. Wyckoff, H. G. Botset and M. Muskat: The Mechanics of Porous Flow Applied to Water-flooding Problems. *Trans.* A.I.M.E. (1932) **103**, 219.

[2] It is to be noted that the pressure distribution of Fig. 4 is for the case in which the spacing between the input and output lines is 1½ times the well spacing within

In Fig. 6 is given the pressure distribution for the seven-spot flood. In a manner similar to that just outlined one may derive from this distribution the immediate explanation for the marked difference in the nature of the advance of the flood in the ordinary and inverted seven-spot arrangements.[3]

With respect to the quantitative results of the analytical treatment of the problem of water-flooding, only the principles of the analytical methods used are outlined here. For that phase involving the calculation of the flood conductivities a formal expression is first set up for the sum of the potential distributions due to all the individual wells of the flooding network in question, the value of the sum representing the resultant pressure distribution in the network. Next, the value of this sum, or of the pressure, is computed for are presentative input well and a representative output well, the difference giving the net pressure differential acting on the system. Dividing this difference into the production rate of the network, per network element, gives the "conductivity" of the network.

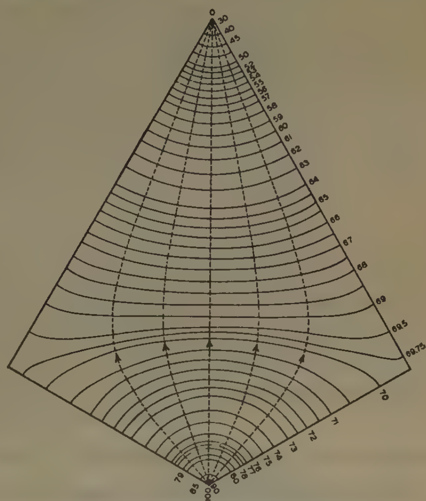


Fig. 6.—Pressure distribution in a seven-spot network.

The results of this procedure as applied to several typical networks are shown in Fig. 7. The abscissas h give the input-output well separations and the ordinates $Q/\Delta p$ the conductivities, or the production rates per *network element* per unit pressure differential per unit sand thickness, in a unit permeability sand. The curve for the line drive is for the case of the regular unstaggered drive where the input-input well spacing equals the input-output distance. The curves run closely parallel, the conductivity of the seven-spot per network element being 39 per cent higher than that of the direct line drive and 6 per cent higher than the five-spot conductivity.

Of more importance than this difference between the several networks is their common feature of being very insensitive to the absolute value of the well spacing. In all cases, increasing the spacing by 100 per cent,

these lines whereas the flood photograph is for an equispaced network. However, from comparison with the pressure distribution of Fig. 3 it is evident that the only effect of the wider spacing between the lines is to increase the area over which the streamlines are essentially parallel; that is, where the flow is linear in character.

[3] See Figs. 15 and 16 of paper cited in reference 1.

as from 400 to 800 ft., decreases the conductivity by only 10 per cent. Thus there is obtained the fairly definite result that the absolute value

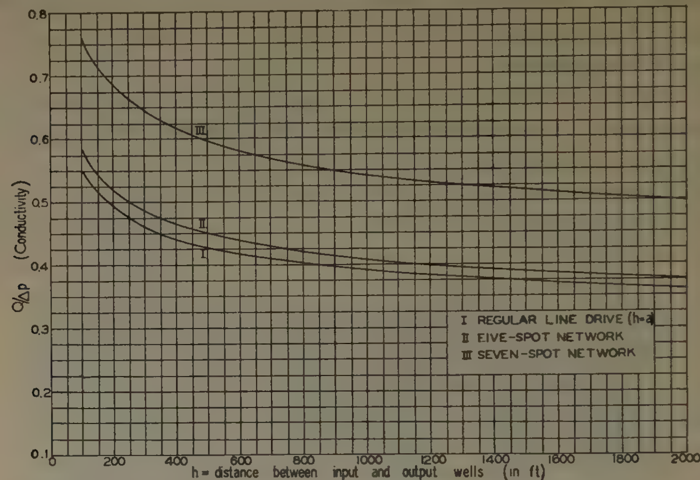


FIG. 7.—CONDUCTIVITIES OF FLOODING NETWORKS AS A FUNCTION OF THE WELL SPACING.
$Q/\Delta p$ = production rate per network element per unit pressure differential in a unit permeability sand of unit thickness.

of the well spacing plays only a minor role in determining the physical value of a flooding network.

With respect to the assumption made in computing curve I, it is to be noted that the regular line drive may be modified both by stretching

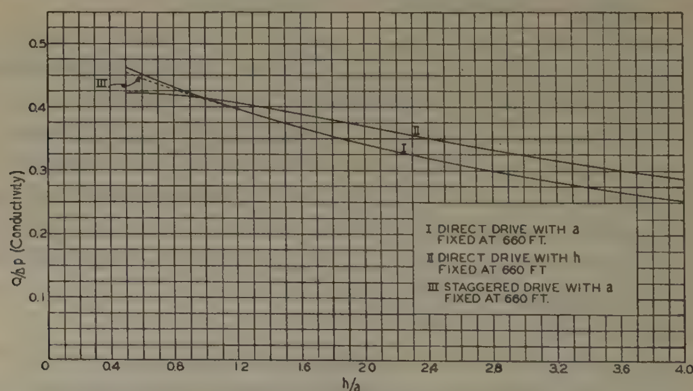


FIG. 8.—CONDUCTIVITY OF LINE-DRIVE NETWORKS AS A FUNCTION OF h/a.
$Q/\Delta p$ = production rate per well per unit pressure differential.
h = distance between input and output lines.
a = well spacing within input or output lines.

or contracting the regular drive; i.e., by changing the ratio h/a and by staggering the drive. Fig. 8 shows the effect on the conductivity of both modifications. In the cases of the unstaggered drives, curve I

refers to a network in which the well spacing within the input and output lines is kept fixed at 660 ft. while the distance h between the lines is varied; the network corresponding to curve II has the input-output line separation fixed at 660 ft., and a variable spacing within the lines. Both of these curves show that the flood conductivity decreases as the network element becomes elongated, either an increased input-output line separation or a decreased well spacing within the lines contributing to the decrease in conductivity.

Finally, the effect on the conductivity of staggering the line-drive flood is to be noted. Curve III gives the results of the computations for a staggered line drive and shows clearly that except for small values of h/a the staggering has an entirely negligible effect on the conductivity, although for values of $h/a < 1$ the conductivity is somewhat lowered by the staggering.

The principle of computing the flood efficiency is even more simple than that for the calculation of the flood conductivities, for it is only necessary to compute the time when the water will first reach the output wells.[4] Multiplying this time by the rate of water input per network element, the result gives the area flooded by the time the water reaches the output wells. Dividing this area by the area of the network element, the flood efficiency will be the quotient.

In contrast to the conductivity of the flooding networks, which were found to vary with the dimensions of the system, even though but slowly, the efficiency of a flooding network and also the shape of the advancing flood depends only on the geometry; i. e., the *shape* of the network. Both the total area of the flood and the shape of the individual stages are independent also of the absolute pressure, but of importance for the present is the fact that they are independent of the well spacing. Thus the efficiencies 72.3 and 74 per cent obtained analytically for the five and seven-spot floods, agreeing well with those previously found by the electrolytic model, are absolute values for these floods and cannot be changed by changes in the well spacing, pressure differential, permeability, etc.

In the line flood, on the other hand, there are two "degrees of freedom" as it were, in specifying its geometry. Thus, it may be stretched or contracted, that is, h/a may be changed, and the wells may be staggered, both changes modifying the geometry of the network. Though there will be an additional infinity of degrees of staggering, we need concern ourselves only with the extreme case where the input and output

[4] It should be mentioned here that in the original paper (*Tech. Pub.* 507) the equations giving the time when water first reaches the output wells as used in determining the flood efficiencies are evidently based upon a 100 per cent porosity and, therefore, must be multiplied by the actual porosity of the sand for numerical computations of the time of flood; i.e., equations 7, 9 and 10 of the text.

wells are mutually shifted so that the members of either set are halfway between those of the other. In both of these ways then, the efficiency of the flooding network can be changed. Fig. 9 shows the magnitudes of the effects. For curve I only h/a is varied, while for curve II the drive is further modified by staggering.

Thus it develops that stretching the line drive increases the efficiency, and also the more significant fact, that staggering has a very appreciable effect on the efficiency, especially for the smaller values of h/a. Thus in the case of $h/a = \frac{1}{2}$, for which the staggered flood is evidently identical with the ordinary five spot, only 43 per cent of the five-spot efficiency would be found if the five-spot were unstaggered. Furthermore, it should be observed that both by the stretching process alone

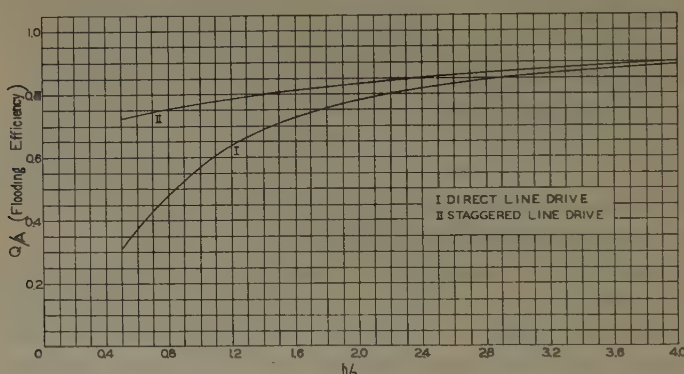


FIG. 9.—FLOODING EFFICIENCY OF LINE-DRIVE FLOODS AS A FUNCTION OF h/a.
Q/A = area flooded per network element at time water first reaches output well.
h = distance between input and output lines.
a = well spacing within input or output lines.

and by the combined stretching and staggering modification even the relatively high seven-spot efficiency of 74 per cent can be exceeded by quite appreciable amounts.

Having thus derived the fundamental characteristics of the various flooding networks, a more exact comparison between them is possible. Returning then, to the conductivities of the networks, as shown in Fig. 7, it is to be noted, first, that the curves here refer to the conductivities per *network element*. But since each seven-spot network element has three wells whereas the five-spot and line-drive elements have two wells each, the element conductivity does not offer a proper comparison between the various floods. Rather, one should compare the conductivities for a given flooded area with the same total number of wells; i. e., with the same well-per-acre densities. This requires first that the spacing be increased in the seven spot by about 7.5 per cent, and then, since there will be only two-thirds as many seven-spot elements in the

given area as five-spot or line-drive elements, the conductivities of curve III must be given a weight of only two-thirds.

With these changes the proper conductivity comparison is shown in the curves of Fig. 10. Here it is seen that the seven spot has an effective conductivity even less than that of the direct line drive, in contrast to an apparent conductivity of 32 per cent higher than that of the five spot.

Thus far, then, the results show that with respect to conductivities the five spot is the most favorable flood, the direct line drive being next and the seven spot last, while with respect to the efficiencies the seven spot is superior to the five spot while the direct line drive is the least

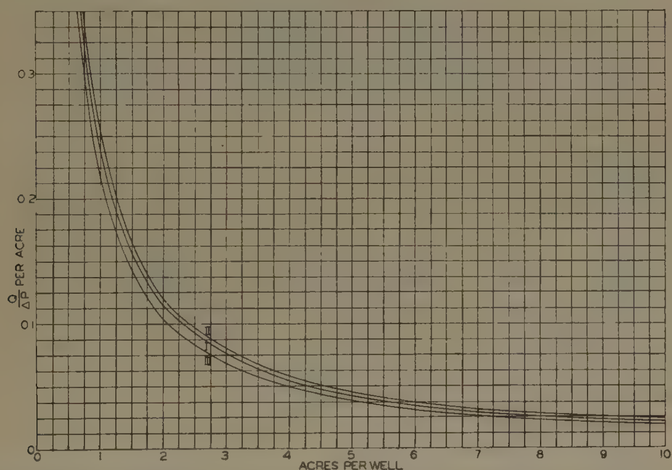


FIG. 10.—CONDUCTIVITIES OF FLOODING NETWORKS AS A FUNCTION OF WELL DENSITY.

efficient. Still this comparison is not complete, for the possibility of stretching and staggering the line drive has not been considered. When this is done we finally arrive at the comparison shown in Table 1. By choosing $h/a = 1.50$ the line-drive flood still has a conductivity slightly higher than the seven spot, while at the same time attaining an efficiency of 80 per cent. Although its *conductivity* is some 12 per cent lower than that of the five spot, the fact that its *efficiency* is 11 per cent higher should more than counterbalance the disadvantage with respect to the conductivity. For the latter can be compensated for by a 12 per cent increased pressure differential, whereas the flood efficiency—as the term is used here—of the five spot can never be raised beyond 72.3 per cent. It may be concluded, therefore, that a staggered line drive with an h/a from 1.5 to 1.6 possesses the most favorable physical features.

As a practical illustration of these comparisons, a specific numerical example approximately corresponding to a Bradford field flooding problem is offered. Thus it will be supposed that there are four 1000-acre

tracts on each of which shall be put 400 wells, including injection and output wells. They will be arranged respectively in the staggered line drive with $h/a = 1.5$, direct line drive, five spot and seven spot. The sand will be supposed to be 40 ft. thick, with a porosity of 10 per cent and a permeability of 0.001 darcys. Table 2 gives the significant data for comparison of the various floods. The superiority of the staggered line drive will be quite evident.

It should be remembered, of course, that no detailed account has been taken of the end effects involved in fitting the networks within the boundaries of the 1000-acre tracts. Rather, it has been assumed that the tracts were simply sections of infinite networks. Furthermore, the initial

TABLE 1.—*Relative Efficiencies of Floods*

	Relative Production Rate (Conductivity for Equal Well-acre Densities)	Flood Efficiency, Per Cent
Staggered line drive. $h/a = 1.50$ $a = 539$ ft.; $h = 808$ ft.	0.383	80.0
Five spot $h_5 = 660$ ft.	0.433	72.3
Regular line drive $h/a = 1.50$ $a = 539$ ft.; $h = 808$ ft.	0.383	70.6
Seven spot $h_7 = 709$ ft.	0.378	74.0

transients due to the compression of the gas have been neglected, and, in fact, the supposition has been made that at the beginning the total porosity of 10 per cent was filled with oil and, moreover, that the oil is completely flushed out by the advancing water. If it be supposed that there will be only a 50 per cent recovery, the times given in the third column from the right in the table will be cut by approximately a factor of ½.

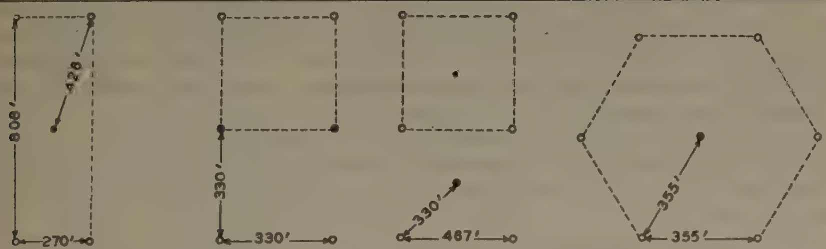
Even with this factor of ½, the times required for the water to reach the output wells are still admittedly larger than the times observed in actual flooding programs by a factor of about 10. Although this may appear to cast doubt upon the validity of the theory presented here, it is rather felt that this discrepancy throws considerable light upon the sand conditions under which such floods as those in the Bradford field have been operating. For it simply shows that there is much more effective water-bypassing in practice than would be possible in an ideal homogeneous sand. That is, it indicates that there must be considerable channeling in the sands, due either to high permeability beds or to considerable streaking of high permeability zones within the main body of sand of

permeability of the order of 0.001 darcy. Another factor that may enhance this channeling is a bypassing of the water through the oil even under uniform sand conditions, much as gas is known to bypass oil in homogeneous sands. The main effect, however, probably is due to the high permeability streaks or beds, for the actual existence of permeability variations up to 100 fold have been found in measurements of cores from the producing sands.

TABLE 2.—*Comparison of Flooding Networks in Ideal Sands*

Total area of tracts, 1000 acres; total number of wells, 400; total pressure differential, 1000 lb.; sand thickness, 40 ft.; sand permeability, 0.001 darcy; sand porosity, 10 per cent; viscosity, 1 centipoise.

	No. Input Wells	No. Output Wells	Input-input Spacing, Ft.	Input-output Spacing, Ft.	Rate of Fluid Input or Output, Bbl. per Day	Time to Reach Output Wells, Yr.	Flood, Per Cent	Total Water Free Prod., 10^7 Bbl.
Staggered line drive, $h/a = 1.50$	200	200	270	426	3776	18.0	80.0	2.48
Direct line drive, $h = a$	200	200	330	330	4094	11.8	57.0	1.77
Five-spot	200	200	467	330	4305	14.3	72.3	2.25
Seven-spot	267	133	355	355	3765	16.7	74.0	2.30



STAGGERED LINE DRIVE

DIRECT LINE DRIVE

FIVE-SPOT

SEVEN-SPOT

Furthermore, it may be pointed out that regardless of the detailed explanations invoked in the analysis of the field data, the term "efficiency" as used here may be taken as a quantitative measure of the effectiveness of a flooding program. And this may be obtained simply by dividing the water-free oil output by the volume of oil in the sand at the beginning of the flooding operations. This result, compared with the theoretical efficiency of the particular network considered, will give a specific measure of the extent of the water bypassing. In fact, we may already conclude, from the general comparison between the theoretically ideal example above and the results of practical field experience, that perhaps the questions of well spacing and arrangement are after all of relatively minor importance in determining the success of a flooding program, and that attention should be concentrated rather upon prevent-

ing bypassing in high-permeability zones as the major problem to be solved before the efficiency of artificial water-flooding can be improved materially.

Returning finally to the question of the absolute well spacing, reference is made to our earlier result, which showed that it has no effect on the flood efficiency and only a minor effect on the conductivity. The problem of well spacing, therefore, must be relegated to the economic side of the question, in which the value of high production rates with a close spacing and large investment must be balanced against lower production rates with wider spacing and proportionately lower investment.

DISCUSSION

(*Frank A. Herald presiding*)

[This discussion followed presentation of the unabridged paper that was issued as T. P. 507 (see footnote on page 62).]

E. A. Stephenson,* Rolla, Mo.—In actual practice the spacings are less, rarely more than 240 ft., usually 175 ft., and the time for the water passing from input to output can be predicted: six to eight months for the appearance of water at the output well.

J. B. Umpleby,† Norman, Okla.—The Bradford technique has made much progress in the five years since I was active in that field. However, my early observation of the practical workings of the five-spot and seven-spot patterns led to the conclusion that there is not a great deal of difference between them. In spacing, the time element becomes very important, and the balance sheet largely controls procedure. The use of natural drive in the Mid-Continent hinges on an appreciation of the work of water, both as a direct and indirect expulsion force. In many cases instead of permitting the removal of water we should require the addition of water, if maximum recovery is our aim. This paper should enhance the general appreciation of what water does underground.

F. A. Herald,‡ FortWorth, Tex.—We have made the oil man gas-conscious, which was an accomplishment; now we must make him water-conscious.

E. A. Stephenson.—There has been some progress made in the delayed flooding system: the water flowed through the more permeable zones, the flow diminishing as the pressure approached that of the pressure heads before producing.

K. B. Nowels,§ Bradford, Pa. (written discussion).—It is very difficult to give an intelligent discussion of this paper, principally because it sets forth some fundamental considerations that should be given to present-day flooding methods and the spacing pattern used in their development. I consider both the present paper and the earlier one[5] important contributions to water-flooding technology. I am not in full agreement with some of the principles we find in the latter paper, particularly since they

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† Geologist and Petroleum Engineer.
‡ Petroleum Geologist and Engineer.
§ Chief Petroleum Engineer, Forest Oil Co.
[5] Reference of footnote 1.

have been developed only through laboratory technique. I am of the opinion, however, that some of the conclusions reached in the present paper can be substantiated by the study and correlation of field data which our organization is now attempting to make in an effort to prove or disprove the principles outlined by Mr. Muskat and Mr. Wyckoff.

Mr. Muskat gives percentage efficiencies of various flooding networks, and I believe that these efficiencies will be proved by the field data we are now working with. It is interesting to know that the regular five-spot network has an efficiency of 74 per cent as compared to the seven-spot efficiency of 79 per cent. It is probable that these percentages can be substantiated, so far as the percentage of area flooded out before water reaches the output well is concerned, but there are other factors to take into consideration. In using the seven-spot pattern, development costs are higher than necessary and the oil operator in most instances would not choose the seven-spot because of its higher cost. For instance, in an imaginary 100-acre lease where a spacing of 200 ft. between oil well and water well is used in both the five-spot and seven-spot flood, it is necessary to drill approximately 143 wells on the lease if the seven-spot pattern is used, as compared to 128 wells for the five-spot.

Muskat and Wyckoff are still of the opinion that spacing is not related to physical factors as much as it is to economics, although the operator experienced in flooding has found that for various spacings the proper pressure must be used in securing the desired recovery. Too wide a spacing for the pressures available will give poor recoveries.

Within the next several months I will be in a better position either to prove or disprove the statements made in the present paper, but wish to say that technologists of the Gulf Research and Development Corporation have given us valuable contributions to flooding technology. They have opened up new lines of thought, which will result in their continued application not only to flooding problems but also to questions concerning natural water drive and water encroachment in the western fields.

H. H. Power,* Tulsa, Okla.—Experience shows that percentage recoveries depend to a large extent upon whether the propulsive medium is hydraulic or merely gas drive with no water. Little can be done to benefit a well by reshooting or cleaning out after it has experienced a natural water drive. Just prior to the appearance of water, a notable increase is often effected in the well's production. This is thought to be due to the "bank" of oil just ahead of the water. As this "bank" passes the well, production declines, and a small amount of oil with large quantities of water are produced thereafter up to the well's economic limit of production. In this last stage of the well's life, cleaning out and shooting are in most cases of small benefit. The sand has been flushed with water, leaving little oil behind.

In fields under gas propulsion, recoveries are a function of gas-pressure decline. If the gas is not wasted and kept in solution, spacing and drilling programs so arranged that gas energy will not be dissipated in moving oil through the sand at too great distances, relatively larger recoveries should result. Cleaning out, reshooting, etc., are often profitable during the settled production period of wells in gas-drive fields. The differential pressure between formation and well bore is increased by removal of cavings, shooting heavily, and by keeping the well "pumped down," thus increasing the rate of production, and in many cases, ultimate recovery. Recoveries in gas-drive fields operated at maximum efficiency may not exceed 20 or 25 per cent, in contrast to recoveries in natural water-drive fields of 50 per cent or more. The above comparison shows that little recoverable oil is left behind after a natural water drive, whereas in a gas-drive field as much oil recoverable by improved methods may remain in the sand as has been produced by natural recovery methods.

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* Production Dept., Gypsy Oil Co.

W. E. Wrather,* Dallas, Tex.—There has been a change of view on edge water. In the past its appearance threw a fright into the producer; now it may be looked upon as a beneficent influence. In Burbank, where the water is essentially static, the anticipated per acre yield is relatively low. In other fields with an active hydrostatic head the anticipated yield is considerably greater. If water incursion can be controlled, and kept on an evenly advancing front, it can be utilized to increase production.

E. Oliver,† Ponca City, Okla.—I call attention to the paper on Persia, by Sir John Cadman, in the Division's 1933 volume,[1] wherein the author says: "No well which was producing in Persia in February, 1929, has since ceased natural flow on account of declining pressure or of diminished drainage from the reservoir rock. No well has been taken off production on account of edge water encroachment, nor has indeed edge water been produced in any production well. A certain number of wells have gone to gas and been closed in, but this is strictly in accordance with our system of operation. The dates on which such wells have gone to gas have corresponded closely with estimates existing four years ago and replacement wells have, where necessary, been methodically completed in advance of these dates. The pressure in the gas dome of the Masjid-i-Sulaiman field has only dropped 5 lb. per square inch, approximately 1 per cent, during the past four years, although a production of nearly 140,000,000 bbl. has been drawn from the field during that period."

Referring to the water problems so typical of American fields, he states: "It is interesting to record that although the Masjid-i-Sulaiman field has sensitive edge water conditions which are readily disturbed by variations in the rates of local production, and although commercial production has been continually drawn from this field since 1911, the oil produced is still water free."

R. D. Wyckoff (written discussion).—In the final analysis, the indicated discrepancy between what the ideal system will do and the results obtained in actual networks provides a suitable criterion whereby the performance of an actual flood may be judged. Thus it appears that in an actual flood the output wells start producing water in one-tenth the time, or less, than would be the case in an ideal flood. Evidently, then, there is more to be gained by attempting to guard against premature channeling of water through highly permeable streaks than in devoting attention to details of spacing, type of network, etc. The authors consider the real value of the analysis to lie not in the numerical results themselves but rather in the fact that they provide a necessary criterion to indicate the most profitable point of attack in the general problem of increasing flooding efficiency. Thus the analysis again points to and indicates the distressing magnitude of the old problem of bypassing. We must find, if possible, some means to prevent water from channeling prematurely through highly permeable streaks.

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* Consulting Geologist.

† Appraisal Engineer.

[6] *Trans.* A.I.M.E. (1933) **103**, 397.

Recent Changes in Reservoir Pressure Conditions in the East Texas Field

By G. L. Nye* and C. E. Reistle, Jr.,† Kilgore, Texas

(Dallas Meeting, October, 1933)

The East Texas field is in Smith, Rusk, Gregg, Upshur and Cherokee counties, Texas. The discovery well was completed Sept. 8, 1930, near the eastern limit of the field. Within less than one year the new field became the dominant factor in the world production of crude oil. On Aug. 16, 1931, eleven months after completion of the discovery well, there were 1644 wells in the field, and the average daily production was 584,475 bbl. Since that time the number of wells has increased to 8195 on Oct. 1, 1933, and the field has produced 385,979,691 bbl. of oil.

The geology of the East Texas field has been discussed by Lahee,[1] Levorsen,[2] Minor and Hanna[3] and others, and it will not be discussed in detail here. The field is a structure of the monocline type on the westward dipping homocline between the Sabine uplift and the East Texas geosyncline. Production is obtained from the Woodbine group, which has been truncated and then sealed by the Austin chalk, which rests unconformably upon it. The oil-saturated part of the sand lies between a sub-sea depth of 3050 ft. on the east side of the field, where the Woodbine sand stops and the Austin chalk rests directly upon older formations, and a sub-sea depth of 3320 ft., which was the average depth of the water table in the sand at the time the field was discovered.

The field is about 40 miles long and has an average width of approximately 4½ miles. The area within the proven limits of the field is close to 116,580 acres and the normal Woodbine water underlies nearly 62,000 acres on the western side of the field at the present time.

The field is unusual in several respects: (1) the tremendous size of the reservoir system and the quantity of oil in place; (2) the large area of the oil and water contact, which makes water movement possible into the oil-bearing part of the structure; (3) the absence of free gas within the main producing sand of the field. Changes in the reservoir pressure during the production history of the field have been greatly affected by

* Petroleum Engineer, The Tide Water Oil Co.

† Chairman, The East Texas Engineering Association.

[1] F. H. Lahee: The East Texas Oil Field. *Trans.* A.I.M.E. (1932) **98**, 279–294.

[2] A. I. Levorsen: The East Texas Oil Field. *Int. Petr. Tech.* (June, 1931) 261–268.

[3] H. E. Minor and M. H. Hanna: East Texas Oil Field. *Bull.* Amer. Assn. Petr. Geol. (1933) **17**, 757–793.

each of these factors, or perhaps we should say individualities of this particular field.

In the last few years there have been a number of important contributions, to our knowledge, dealing with the flow of fluids through sands, and this information, together with the study of actual reservoir pressures and the sampling and analyses of crude oil and gas solutions under actual reservoir conditions, has made it possible to obtain a clearer conception of the behavior of underground reservoir systems. In the past we have studied and been concerned only with that part of the reservoir system containing oil and gas, but now we find that this is not enough. It is necessary also to have knowledge of the entire reservoir system, which may extend for several hundred miles in all directions from the field. It is the behavior and movement of the fluids within the entire reservoir system that control the actual performance within the oil and/or gas-bearing portion of the reservoir.

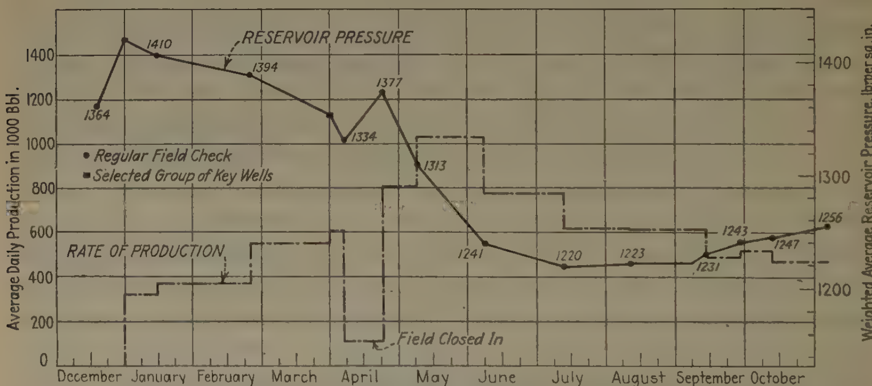

FIG. 1.—RESERVOIR PRESSURE, WEIGHTED AVERAGE CORRECTED FOR −3300 FEET SUB-SEA.

In Table 1, the weighted average reservoir pressure and production data are given for the East Texas field for the period Oct. 25, 1932 to Sept. 27, 1933. In Fig. 1, the weighted average reservoir pressures (corrected to a base of −3300 ft. sub-sea) of the East Texas field are given for the period January to October, 1933. The average daily production for the periods covered by the reservoir pressure data is shown also on the same curve.

It is apparent from the data in Fig. 1 that the decline in reservoir pressure is a function of the rate of production. The sharp increases in reservoir pressure during the period Dec. 18 to 31, 1932, and April 6 to 23, 1933, are the result of closing in the field completely. While the field was operated under a production rate of from 300,000 to 400,000 bbl. per day the loss in reservoir pressure decreased from 2.99 lb. per sq. in. per million barrels produced during the period Dec. 31, 1932 to Jan. 14,

1933; to 1.04 lb. per sq. in. per million barrels produced for the period Jan. 14, 1933 to Feb. 25, 1933. When the rate of production was increased during the latter part of February and March, the rate of reservoir pressure decline was again increased. During the period in April, 1933, while the field was shut in the average reservoir pressure again increased. Following this period when the field was shut in the field was produced at a rate of from 800,000 to 1,000,000 bbl. per day during the latter part of April, May and June, and a very sharp decrease in reservoir pressure occurred. This was during the latter part of May and the early part of June, 1932, when so many wells on the east side of the field stopped flowing naturally as a result of low reservoir pressure. Fortunately, from July, 1933, until the present time, October, 1933, the rate of production has been gradually decreased until the production is now approximately 487,000 bbl. per day. As a result of the decrease in the rate of production, the average reservoir pressure of the field has increased from a low of 1220 lb. per sq. in. on July 12, 1933 to 1243 lb. per sq. in. on Sept. 27, 1933.

This increase in the average pressure of the part of the reservoir system containing oil, as the rate of oil production was decreased but not stopped, is perhaps the most definite proof that the withdrawal of oil from the reservoir is accompanied by replacement with water from the part of the reservoir system extending beyond the limits of the oil-productive portion of the reservoir system. If the oil had not been replaced by water, it would have been necessary for the oil and gas solution remaining in the reservoir to expand and occupy this space created by the removal of the oil that has been produced. Using the pressure, volume data obtained by Lindsly[4] in his experiments with bottom-hole samples obtained from the East Texas reservoir, we find that the average reservoir pressure would now be 645 lb. per sq. in. if such a condition existed. Furthermore, the expansion of fluids, whether oil or gas, or a combination of these substances could hardly result in an increase in the average pressure of a reservoir system. It is this movement of water into the reservoir that supplies the pressure energy that has controlled the reservoir pressure within the oil-bearing part of the reservoir system. While engineers have long recognized the energy available in compressed gases and the utilization of this energy in the propulsion of oil and other fluids through sands to regions of lower pressure, little or no thought had been given to the energy available from compressed liquids until Dr. H. D. Wilde, Jr., and T. V. Moore[5] advanced this

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[4] B. E. Lindsly: A Study of "Bottom-Hole" Samples of East Texas Crude Oil. U. S. Bur. Mines *Rept. of Investigations* 3212 (1932).

[5] H. D. Wilde, Jr. and T. V. Moore: Hydrodynamics of Reservoir Drainage and its Relation to Well Spacing. Amer. Petr. Inst. *Proc.* (1932) 83–91.

explanation as one source of energy causing the movement of the fluids within reservoir system.

At first thought, one might be inclined to disregard this factor as of minor importance, but using the compressibility figure for East Texas crude oil under reservoir conditions as obtained by Lindsly, we find that the remaining oil in place in the East Texas reservoir has expanded approximately 25,800,000 bbl., as a result of the reduction in reservoir pressure from the original pressure of 1620 lb. per sq. in. to the present pressure of 1243 lb. per sq. in. With these figures in mind, the magnitude of the energy available in the fluids (water, gas and oil) in the Woodbine sand surrounding the East Texas field can readily be conceived as sufficient to propel the water into the oil-bearing portion of the system.

The pressure conditions within the oil-bearing part of the East Texas field can be explained, therefore, when the entire reservoir system, embodying not only the oil-productive part of the Woodbine sand but the entire Woodbine sand in the area extending to the north, west, and south of the field, is taken into consideration. When oil is produced from the field, a corresponding reduction in pressure results. This reduction in pressure causes movement of the fluids from the areas of higher pressure towards the low-pressure area. If it were not for the fact that the movement of fluids through the reservoir sands is accompanied by a loss of pressure energy, which is consumed by frictional resistance, there would be a very rapid movement of the fluids into the low-pressure area and the pressure of the entire system would be adjusted in accordance with pressure-volume relationships of the fluids within the reservoir system. However, as fluids flow through sands there is an accompanying loss of pressure, which increases with increased rates of flow. Therefore, as the rate of withdrawal of oil from the reservoir is increased there is a correspondingly greater frictional resistance to the movement of the oil and water and the pressure at the discharge end of the system or, in other words, within the oil-producing part of the reservoir system, declines more rapidly. Likewise, as the rate of production is decreased, less frictional resistance results, and the fluids move into the oil-producing part of the reservoir system with less loss of pressure energy, and the pressure within the reservoir increases until a condition is established wherein the pressure within the oil-producing portion of the reservoir is in equilibrium with the new rate of flow. Once equilibrium is established the pressure within the oil-bearing reservoir will decline in accordance with the new conditions.

The decline in reservoir pressure in the East Texas field resulting from the high rates of production during the months of April, May and June, 1933, indicated that by June, 1934, at least 25 per cent of the wells in the field would require pumping. The curtailment of production during the months of July, August, September and October, 1933, has

TABLE 1.—*Data on Production and Reservoir Pressure*

Date	Duration, Days	Cumulative Production, Bbl.		Production during Period, Bbl.		Reservoir Pressure, Lb. per Sq. In.		Per Million Bbl., Lb.	
		Start	End	Total	Daily Av.	Start	End	Drop	Gain
Oct. 25 to Dec. 18, 1932	55	206,158,300	226,956,410	20,798,100	378,144	1408	1364	2.11	
				(Field closed in)					
Dec. 18 to Dec. 31, 1932	14	226,956,410	226,956,410	0	0	1364	1424 (est.)	No prod.	40
Dec. 31, 1932 to Jan. 14, 1933	14	226,956,410	231,641,650	4,685,240	334,660	1424	1410	2.99	
Jan. 14 to Feb. 25, 1933	42	231,641,650	246,969,070	15,327,420	364,939	1410	1394	1.04	
Feb. 25 to Mar. 30, 1933	33	246,969,070	265,208,907	18,239,837	552,720	1394	1358 (est.)	1.97	
Mar. 30 to Apr. 6, 1933	6	265,208,907	268,919,158	3,710,251	618,375	1358	1334	3.77	
				(Field closed in)					
Apr. 6 to Apr. 23, 1933	18	268,919,158	270,927,620	2,008,462	118,581	1334	1377		21.4
Apr. 23 to May 8, 1933	15	270,927,620	282,982,229	12,054,609	803,640	1377	1313	5.30	
May 8 to June 8, 1933	31	282,982,229	314,104,321	31,122,092	1,029,000	1313	1241	2.31	
June 8 to July 12, 1933	34	314,104,321	340,635,622	26,531,301	780,332	1241	1220	0.792	
July 12 to Aug. 11, 1933	30	340,635,622	359,160,884	18,525,262	617,508	1220	1223		0.162
		Federal Government Oil Code 25 Per Cent Reduction Effective Sept. 7, 1933							
Aug. 11 to Sept. 13, 1933	33	359,160,884	379,160,884	20,306,000	615,334	1223	1231		0.395
Sept. 13 to Sept. 27, 1933	15	379,160,884	385,979,691	6,818,807	487,043	1231	1243		1.760

resulted in an actual increase in reservoir pressure and at the present time indications are that less than one per cent of the wells that are now flowing will require pumping prior to June, 1934.

Under the present rate of production the average vertical movement of water into the oil-producing sand is somewhere between ⅛ and $\frac{1}{10}$ in. per day. The slow encroachment of water undoubtedly has greatly increased the recovery of oil from the sand that has been flooded by water. Information at the present time indicates that a recovery of between 65 and 75 per cent of the oil has been obtained from the flooded portion of the sand. This high recovery can be attributed to the slow movement of water into the sand, and the fact that maintenance of the reservoir pressure above the saturation pressure of the oil and gas solution has prevented any increase in the viscosity and surface tension of the oil.

A study of the reservoir pressure conditions, and the reaction of these pressures to different rates of production, clearly indicates that a greater efficiency can be obtained from the natural forces available for the recovery of oil by the proper control of the rate of production. In fields where a natural water drive is available, the magnitude or efficiency of the water drive is undoubtedly a function of the rate of movement required for the water to replace the oil that is produced. The regulation of the production rate can be and should be regulated so as to obtain an efficient utilization of this natural energy. This will result in longer natural flowing life, lower lifting costs, less trouble from uneven water encroachment and a greater ultimate recovery of oil.

DISCUSSION

(*H. D. Wilde, Jr. presiding*)

R. D. Wyckoff,* Pittsburgh, Pa.—I believe the correlation between the reservoir-pressure decline and the fluid output of the field can be shown more clearly by considering the "effective" pressure rather than the average pressure of the field. The effective pressure may be considered as the average pressure of the western quarter of the field. In this manner the west-east pressure gradient across the field, which varies with the production rate and introduces spurious transient effects, may be partly eliminated. We have found such a procedure necessary in analytical studies of the reservoir performance.

If it is assumed that the East Texas field is operating on a combined water and gas drive it is possible to calculate a pressure-decline curve that fits quite accurately the observed curve over the early history of the field. However, on this basis it is impossible to explain adequately the rapid increases in pressure that have been observed during "shut-in" periods unless complicated explanations involving gas supersaturation effects are introduced. On the other hand, using the compressible fluid theory introduced by Wilde and Moore and applying it to the water horizon on the assumption of a complete water drive, remarkably close agreement is obtainable between calculated and observed effective pressures. An interesting feature of the application of the theory is the high apparent compressibility of the water horizon that is required. Thus our calculations indicate that the compressibility is of the order of 10 times that normally observed for water.

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There is much in the compressible fluid theory and the reaction of the field pressures to the sharp changes in production rate add considerable evidence in support of it.

The oil industry would do well to determine the regional distribution of pressure throughout the water areas instead of plugging the water wells. Undoubtedly some interesting and valuable information could be obtained if such procedure were practicable.

T. V. Moore,* Houston, Tex.—The only plausible explanation of pressure maintenance in East Texas is that water is entering the field. The pressure is declining, which indicates that water is entering the Woodbine because of its own expansion or expansion of associated fluids. I do not believe the pressure is maintained by expansion of water alone; it may be due to expansion of gas pockets near the field.

D. C. Barton,† Houston, Tex.—At Goose Creek and Jennings as the oil was extracted there was some slumpage; there is some indication therefore that the overburden maintains some weight on the oil.

C. E. Reistle, Jr.,‡ Bartlesville, Okla.—The waters from sources other than the Woodbine sand differ appreciably in their chemical analyses, but the waters from the Woodbine sand are surprisingly uniform in their chemical content.

L. G. E. Bignell,§ Tulsa, Okla.—There hardly seems to be any direct comparison between the conditions suggested by Dr. Barton as observed in Gulf Coast fields, where sand has been produced with the oil in relatively large quantities, and the East Texas field. There has been a relatively small amount of sand produced with the oil or bailed from the East Texas wells, which may be accounted for by the secondary cementation of silts, sands and conglomerates in this group of beds as suggested by H. E. Minor and Marcus A. Hanna.[1]

W. V. Vietti,‖ Cisco, Tex.—We have no reason to believe that the field pressure should build up quickly. Many individual wells require an hour to reach their maximum bottom-hole pressure. This bottom-hole pressure is then an average of the surrounding bottom-hole pressure of the field and is an instantaneous value, the summation of the effect of all the offset wells and the general withdrawal from the field. It is reasonable to presuppose that 24 hr. will not be long enough to secure a redistribution of pressure within the field, let alone the entire connected reservoir. We are observing pressures in wells taken while the remainder of the field is producing and discussing pressures in the field, which is another matter.

P. P. Gregory,¶ Iraan, Tex.—I have observed that the decline in pressures in closed-in wells was the same at the same elevation as in producing wells near by.

J. B. Umpleby,** Norman, Okla.—There may be an actual dead-weight pressure that steps up production by decreasing reservoir volume. There is a considerable amount of accumulating information that can be thus explained. It would seem that such a phenomenon might or might not be evidenced by measurable surface slumping.

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[1] H. E. Minor and M. A. Hanna: East Texas Oil Fields. *Bull.* Amer. Assn. Petr. Geol. (1933) **17.**

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** Geologist and Petroleum Engineer.

Basic Data for Oil and Gas Wells*

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The natural gas industry is essentially a byproduct of the oil industry. When first discovered the gas was usually regarded as a nuisance, and even when found immediately associated with oil, or suspected to be so, it was customary to blow it freely into the air, in the hope that gas would shortly be replaced by a flow of oil. The early methods of production,[1] transportation, and utilization were neither economical nor efficient; the chief value of gas was based on its use as a fuel, with no regard to (1) its effect upon the oil with which it was associated, (2) its importance as a lifting agent, or (3) to its possibilities for the manufacture of byproducts.

The spread of scientific research among major gas and oil companies, manufacturers, and academic groups, has gradually brought recognition of the fact that many of the technical problems bearing on production, transportation and utilization are common to both the gas and the oil industry. A few of the problems that have received serious study, and from which highly gratifying results have been obtained, are: (1) gas measurement, (2) oil well and gas well capacity tests, (3) elimination of field waste, (4) design of pipe lines and compressor stations, (5) extraction of constituents which might interfere with the normal flow of gas through the line, (6) control of reservoir pressure, (7) estimation of reserves of both oil and gas, (8) control of water encroachment, (9) measurement of factors which influence fluid movement through sands, (10) solubility of gases in oils, (11) effect of dissolved gases upon the properties of the solution. These investigations have demonstrated that almost every problem relating to oil production also involves some phase of natural gas engineering.

During the past 15 years the use of experimental methods for the discovery and measurement of obscure, influencing factors, which cannot be determined purely by hydrodynamic or thermodynamic analyses, have contributed much towards the progress made in solving the problems of the oil and gas industries. Most of the experimental work on

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* This paper is based largely on the natural gas symposium that was held at the Dallas meeting, October 6, 1933.

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[1] Specific references are omitted from the greater portion of this paper, but the accompanying bibliography attempts to include the majority of publications that bear on the topics discussed.

gas problems has been limited to dry gas and unconsolidated sands in the laboratory, but other studies have been successfully completed with actual sand cores, and with wells producing oil, or gas, or both. In the case of oil associated with gas, the data obtained through experimentation with these mixtures provide valuable information which is directly applicable to production problems.

The necessity for complete and accurate well and production data, including the geological, physical and chemical factors that control the characteristics of the reservoir fluids, cannot be emphasized too strongly as the foundation upon which an ideal development and operating program must be based, or upon which sound estimates of reserves must stand. Whether the problem be the determination of the open-flow capacity (or the potential) of gas or oil wells, the flow of fluids through the reservoir, or the estimation of reserves, the measurement of gas will be necessary. An understanding of the chemical and physical laws governing the behavior of confined gas, oil and water, or mixtures of these, at various temperatures and pressures, is therefore imperative.

Methods are now available by which the texture, shape and size of the grains and the amount of cementing material in the rock, as well as the shape and size of the pore spaces which in part control the behavior of the fluids in contact with the minerals that compose the reservoir strata, can be studied experimentally. The effect of these characteristics upon the total reservoir capacity and the quantities of oil and gas recoverable through different methods of production can also be evaluated, at least collectively.

Well Data

In general, the information now available for any of the developed oil and gas fields lacks certain desirable data that could only have been obtained when the field was new, but the significance of which may not have been realized at that time. In the light of present-day research, at least the following data should be obtained and recorded for *every* initial productive well in *every* field. (Some of these can also be obtained for the dry holes.) Subsequent to discovery, certain key wells should be selected from which similar data may be obtained periodically:

1. Depth of the well: elevation of well head.
2. Log of the well, showing casing procedure, water, gas and oil shows, and position of cement. State whether or not well was shot, or treated with acid, quantities used, results.
3. Waters encountered; specimens should be saved, the depths recorded, and the waters analyzed as soon as possible.
4. Sand penetration.
5. Shut-in pressure at the well head, preferably taken with a dead-weight tester; at least a newly calibrated spring gage should be used.

6. Capacity tests. Under this should be recorded the diameter of the flow pipe, the temperature, pressure and the gravity of the fluid, and if gas, the bases on which the volume is computed. The duration of the test, the maximum capacity, or the capacity per unit of time per unit of pressure drop should be computed.

7. Bottom-hole data. Temperature, pressure, sample of gas and/or oil taken with well shut in.

8. Properties of reservoir fluids. A complete laboratory study should be made at once of the viscosity, surface tension, and specific gravity of the oil at reservoir temperature and pressure. The solubility of the gases, and the changes in the above physical properties of the oil which occur as gas is withdrawn from the solution should also be investigated.

9. Gravity of the gas; chemical composition; calorimetric determination of B.t.u. value; gasoline content per M. cubic feet.

10. Core samples. As many cores as possible should be preserved and tested for permeability and porosity.

Of the above, 1, 2, 3, 4 and 9 are commonly available in some form or other for most wells, and are not discussed further.

Pressure Data

Well-head pressure data should always be supplemented by detailed information concerning the environment of the locality at the time the pressures are taken, such as: (1) the drilled density of the area, (2) whether adjacent wells were within the drainage influence of the one tested under "shut-in" conditions at the time the test was made, (3) if near-by wells were "in the line," what was their casinghead pressure, what was the line pressure against which they were "working," what volume of gas and/or oil was being delivered at the time, (4) how long these wells (if close by or in densely drilled area) were in the line before the key well was tested.

If the test of a gas well is made during or shortly after a period of "peak loads," the results of calculations based thereon will be misleading because of the low-pressure areas that develop during such periods. Equilibrium cannot be established in large fields, or in many types of reservoirs, unless the field is shut in for several days. In some West Virginia and Kentucky gas fields months are required to build up maximum reservoir pressures after heavy winter withdrawals, consequently under normal operating conditions the most reliable reservoir pressures are obtainable only during the summer or early fall months.

If the well is wet—i. e., contains fluid—a bottom-hole pressure gage should be used, or it must be thoroughly freed from oil or water before reliable pressure tests can be made with the steam or tube gage.

Capacity Tests

The capacity of gas wells may be determined by the "minute pressure method," Pitot tube measurement, orifice or other meter measurement and the "back-pressure-capacity method," which is a series of metered flows taken under different pressure gradients. The latter method was developed by the U. S. Bureau of Mines and the American Gas Assn. (Pierce & Rawlins, U. S. Bureau of Mines, Serial Numbers 2929 and 2930, May, 1929) and is superior to other methods because of its simplicity, because very little gas is wasted in comparison with other open-flow methods, and because of the accurate data acquired. The latter include: (1) the rate of delivery expressed as cubic feet per 24 hr. at 14.4 lb. per sq. in. and 60° F.; (2) absolute reservoir or "shut-in" pressure at the sand, corrected for weight of gas column; (3) absolute back-pressure at sand face in the well corrected for weight of flowing gas column and drop in pressure due to friction in producing string; (4) specific gravity of gas; (5) temperature of gas; (6) internal diameter of producing string; (7) length of pipe.

The volume and pressure measurements thus obtained are applicable only to the particular well. The data can be used: (1) to control deliveries at different back-pressures with a nearly constant formation pressure, (2) to calculate the ability of the well to deliver definite quantities of gas to pipe lines under various working pressures, (3) by the use of assumed dimensions of the radial reservoir cross-section through which the volume of gas flows under the specific pressure gradient, it is possible to calculate roughly the effective permeability of the pay zone in the vicinity of the well; (4) the accurate pressure determinations used in this method furnish fundamental data which are a vast improvement over the usual "catch as catch can" so-called pressure determinations frequently taken for operating purposes.

These accurate pressures for individual wells, taken with the dead-weight tester or a properly tested spring gage of correct pressure range to fit the conditions, can also be utilized to define pressure zones and compute the weighted average pressure for the field. From these average reservoir pressures, as of successive dates, the true pressure decline can be calculated; the latter may be used in conjunction with the metered volume of gas produced during the pressure drop, to determine the remaining reserves. Pressure data from individual wells can also be used to determine drainage interference and thus aid in the proper spacing of the wells and in outlining economical drilling programs.

A similar method is used for the determination of the open-flow capacity, or potential, of oil wells. The information required is (1) shut-in bottom-hole or reservoir pressure, (2) a series of measured production rates taken with several different bottom-hole flowing pressures.

The logarithmic plot of such data is similar to that for gas wells, except that in the latter case the differences in the pressures squared are used. Extrapolation of the lines to zero pressure differential affords a theoretical value for the well potential or open-flow capacity. On account of the weight of the fluid in the hole, the absolute potential or open flow cannot be actually measured, but the extrapolated or theoretical results afford a sound basis for the comparison of the well capacities, without the usual waste and hazards that accompany the ordinary capacity tests.

Bottom-hole Data

The use of bottom-hole devices, which record temperature, pressure and inclination, has increased rapidly during the past five years, and has contributed extensively to a knowledge of reservoir conditions. Bottom-hole samples can now be secured at the identical pressures and temperatures of the reservoir. The results to be obtained through the investigation of such samples will be of far-reaching importance.

Properties of Reservoir Fluids

Many phases of production engineering, such as operating methods, rates of withdrawal and ultimate recovery, are closely linked with changes that take place in the characteristics of the reservoir fluids after production has been initiated. Since for the most part these changes appear to be functions of the variables, temperature, pressure and solubility, the ideal time to acquire fundamental data as to the effect of these variables upon the reservoir contents would be immediately after the reservoir has been penetrated. Hence the initial well should be shut in and a bottom-hole sample of the reservoir fluids obtained, to serve as the standard with which all future samples can be compared. These samples should then be carefully studied for the effects of reduced pressures and temperatures on the solubilities of the gases, and also for the accompanying modifications in the physical properties of the fluids. As the field is developed, key wells should be selected from which similar samples can be acquired, and the entire procedure of sampling and testing should be repeated periodically in order to ascertain the fundamental changes that have taken place with the reservoir.

While it is not yet possible to evaluate the combined effects upon the reservoir and its contents engendered by the variables mentioned, this is largely due to insufficient data. Certain it is that changes in the composition and properties of the gas and oil take place as the pressures are reduced, and if the basic data for each reservoir can be secured, then supplemented periodically by similar data, it will in time be possible to apply the results to operating problems. In the long run the value of the data will far outweigh the cost of acquisition.

Core Samples

In this connection it must be pointed out that a uniform porosity or permeability never exists, either vertically or horizontally, for any great distance in any reservoir strata. The connected permeable zones contain the only "effective porosity" in any formation. The permeable, "effective porosity" zones, plus open joints, bedding planes, channels, fractures, cavities, etc. (which cannot be evaluated from cores recovered) constitute the "pay" portion of the formation. Usually there is considerable difference between the "pay" and the sand thickness recorded in well logs as having been penetrated by the well. Consequently it is imperative to examine numerous complete cores taken from scattered wells throughout the field. This should be supplemented or replaced by accurate measurements of the increase or decrease in the volume and pressure of gas wells and the increase or decrease of the gas-oil ratio for oil wells while "drilling in," so as to determine within reasonable limits the thickness of the pay portion of the producing formation. The accuracy of the porosity-area method of estimating oil and gas reserves is dependent in a large measure on the accuracy with which the thickness of pay zone is determined.

The term "porosity" should be confined to the percentage of voids in the rock. Effective porosity should be limited to the voids that not only constitute oil, gas and water reservoirs but that are so continuously connected, and of sufficient size, that their confined fluids can be recovered, even at the minimum differential pressure at which the reservoir will be operated during the economic life of the field. In spite of a high percentage of voids the rock can be practically impervious, owing to the lack of effective porosity.

Permeability must be distinguished from porosity as so often loosely used. It is "the volume of a fluid of unit viscosity passing through a unit cross-section of the material under a unit pressure gradient in unit time." (See reference 82 in bibliography.) For the same porous medium, fluid and time unit, the permeability factor is not constant if there is a change in temperature, or in the pressure gradient.

It is highly desirable that an instrument be devised that will not only cut the core but bring it to the surface without the loss of any of its contents. Saturation tests performed on cores taken by usual methods rarely reflect the true character of the sand in place, and until such an instrument is available, saturation tests must be regarded as approximations.

Summary

The intimate association of oil and gas in reservoirs, and their similar behavior under many conditions, together with the marked changes

which result from their mutual solution, show that the problems that relate to oil and to gas can scarcely be dissociated from one another. Far more ample well and laboratory data are needed, to provide a broader engineering basis for the oil and gas industry; when such information becomes available, its interpretation and application can well be left to the skill of the engineer.

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Effect of Gas Withdrawal upon Reservoir Fluids*

By Ben E. Lindsly,† Bartlesville, Okla.

(Dallas Meeting, October, 1933)

The withdrawal of gas and/or oil in appreciable quantity from a natural oil reservoir causes the pressure within the reservoir to diminish, and if the oil is completely saturated with gas, this dissolved gas begins to evolve from solution. The liberation of gas from solution in oil causes the oil to change in several ways, the principal changes being: (1) reduction in volume or "shrinkage"; (2) increase in specific gravity (decrease in degrees A.P.I.); (3) decrease of energy in the oil; (4) increased viscosity; (5) increased surface tension.

As the writer's investigations have been concerned more with the first three items than with changes in viscosity and surface tension the following discussion relates particularly to the volumetric shrinkage of the oil, to the increased specific gravity, and to the decreased energy in the oil, each caused by the liberation of dissolved gas.

One of the most surprising facts that have developed in the study of high-pressure well-head and "bottom-hole" samples is the great reduction in volume that occurs in some oils when the naturally dissolved gas is liberated. High-pressure samples taken from well heads in the Oklahoma City, Kettleman Hills and Ventura, Calif., fields decreased in volume from 11.2 to 40.5 per cent when the dissolved gas was liberated in reducing the pressure on the sample to atmospheric.

The amount of shrinkage an oil undergoes when gas is liberated depends upon the quantity of gas liberated and also upon its composition. A given volume of the heavier gases, propane and butane for example, will occupy more space in the oil than an equal volume of methane. The reason for this probably is that the molecules of the heavier gases are larger than those of the lighter gases. When gases are not in solution, and particularly when they are at low pressures, the distance between the gas molecules is so much greater than the dimensions of the molecules themselves that the mere size of the molecules has little effect upon the space occupied by the gas. Avogadro's hypothesis, which in effect states that all gases under the same conditions have the same number of molecules per unit volume, relates to this phenomenon. The fact that the heavier gases occupy more space than the lighter gases in the oil, and

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consequently cause greater shrinkage when liberated from solution, is brought out conclusively when curves are constructed to show the volumetric changes an oil sample undergoes when gas is liberated by reducing the pressure on the oil sample.

Such curves have been shown by the writer.[1] In Fig. 2 of the paper referred to a well-head sample of Kettleman Hills light-gravity crude oil shows a total shrinkage of approximately 37 per cent. Half of this shrinkage took place in reducing the pressure from 1672 to 273 lb. per sq. in. absolute, and the other half (18.5 per cent) took place in reducing the pressure from 273 lb. per sq. in. absolute to atmospheric. It required the liberation of 844 cu. ft. per barrel to accomplish the first 18.5 per cent reduction in volume, whereas the remainder of the shrinkage was accomplished by the liberation of 418 cu. ft. per barrel. The reason that 418 cu. ft. per barrel when in solution occupied the same space that 844 cu. ft. per barrel occupied can be understood if the analyses of the gas are considered. The 844 cu. ft. that caused the first half of the shrinkage was composed of 85.7 per cent methane, 8.77 per cent ethane, 3.47 per cent propane, 1.83 per cent butane, and 0.21 per cent pentane. The analysis of the 418 cu. ft. per barrel that caused the last half of the shrinkage was 27.3 per cent methane, 30.13 per cent ethane, 26.82 per cent propane, 11.92 per cent butane, and 3.50 per cent pentane.

The foregoing example, with one important exception, illustrates what has been found in all samples taken to date from the well head and from the bottom of the hole in fields of East Texas, Seminole, Oklahoma City and California. The single exception relates to a "bottom-hole" sample taken recently from the Crescent field, Okla. (bottom-hole pressure, 2814 lb. per sq. in.). This sample did not show the expected high rate of shrinkage over the low-pressure range. Its shrinkage curve showed a straight-line relationship over nearly the entire range of pressure reduction from 2575 lb. per sq. in. absolute (the saturation pressure of the sample) to atmospheric pressure. From 100 lb. per sq. in. to atmospheric pressure the curve departed from the straight-line relationship and in this respect was similar to previous samples. The writer understands that E. P. Weatherly, Humble Oil & Refining Co., has shown results on "bottom-hole" samples from the Hobbs Field similar to those the writer has described as typical of the Kettleman Hills, Ventura, East Texas and Oklahoma City fields in that shrinkage, which takes place over the low-pressure range, is large compared to the total shrinkage.

With reference to the change in gravity due to liberation of dissolved gas, Beecher and Parkhurst and Dow and Calkin showed several years ago, and W. N. Lacey more recently, that putting gas into solution caused

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[1] B. E. Lindsly: Solubility and Liberation of Gas from Natural Oil-gas Solutions. U. S. Bur. Mines *Tech. Paper* 554 (1933).

the oil to become lighter and, conversely, liberating gas from solution had an opposite effect. The writer has found that these facts are more evident in natural oil-gas solutions taken either from the bottom of the hole or at high pressure from the well head. For example, the output from a well in the Oklahoma City field that produced 39.9° A.P.I. oil was probably 62.6° A.P.I. before the liberation of 430 cu. ft. per barrel over a pressure range of 1103 lb. per sq in. to atmospheric pressure. Similar data on Kettleman Hills oil indicate that 61° A.P.I. oil was 102.3° A.P.I. when it held in solution 1263 cu. ft. per barrel at 1672 lb. per sq. in. pressure.

The withdrawal of gas causes a shrinkage of the liquid volume of an oil pool regardless of whether or not oil is produced. This creates gas spaces in the sand body and tends to promote bypassing of gas which might have been able to perform some useful work in driving oil toward a well. Some of the gas liberated from solution finds its way to the gas cap and becomes a part of the free or extraneous gas. Also, where the oil-bearing formation is a fine-grained sand, some of the gas liberated from solution probably remains within the oil body in the form of minute bubbles. Such bubbles undoubtedly would interfere with the free flowing of the oil within the sand body.

The loss of energy in the oil due to the liberation of dissolved gas is important. Experiments on "bottom-hole" samples in East Texas[2] showed that the oil contained between 330,000 and 430,000 ft-lb. of energy per cubic foot. This energy is due to the gas in solution, which evolves and expands upon reduction of pressure. At 100 per cent efficiency only 170,000 ft-lb. would be required to raise 1 cu. ft. of East Texas oil to the surface. However, as the lifting of oil by the expansion of its dissolved gas is rarely over 20 per cent efficient, the importance of conservation and development of greater efficiency of utilizing the energy in the dissolved gas becomes apparent.

No data have been given regarding the increased viscosity and surface tension resulting from liberating gas from solution in oil. Others are present who have done considerable work along that line. However, it must be apparent that increasing the specific gravity of an oil by removing its lighter constituents must result necessarily in increasing its viscosity and surface tension, because the lighter constituents invariably have low viscosity and low surface tension. The removal of constituents having low viscosity and surface tension, therefore, will result in increasing the viscosity and surface tension of the residual oil.

In conclusion, the withdrawal of gas from an oil pool reduces the energy in the dissolved and in the free gas, causing the oil to shrink in

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[2] B. E. Lindsly: A Study of "Bottom-hole" Samples of East Texas Crude Oil. U. S. Bur. Mines *Rept. of Investigations* 3212 (1933).

volume, creating voids and minute bubbles within the oil body. This condition increases the resistance to flow. Increased resistance to flow also develops through increased viscosity and surface tension of the residual oil. Hence the unnecessary withdrawal of gas from an oil pool should be studiously avoided, as such withdrawal decreases the ultimate recovery of oil and thereby violates the principles of conservation.

DISCUSSION

(L. J. Pepperberg presiding)

C. E. Reistle, Jr.,* Kilgore, Tex.—I found that it was possible, in the East Texas field, to determine the gravity of the oil as it entered the well and the decrease in volume of the oil when brought to the surface by use of bottom-hole pressure data. The results of my tests indicated that the East Texas oil in the reservoir has an A.P.I. gravity of 56.2° and that the volume of the oil decreased 17 per cent when brought to the surface and measured under atmospheric pressure and at a temperature of 60° F. The A.P.I. gravity of the oil under these conditions ranges from 36° to 40°.

I believe that our present-day knowledge of reservoir conditions and the movement of oil and gas within the reservoir sand clearly indicates the value of retaining a maximum quantity of gas in solution in order to maintain a low viscosity and surface tension for the oil. If this is done I believe much greater recoveries of oil will be obtained.

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* Chairman, East Texas Engineering Association.

A New Method for Measuring Vented Gas

By C. M. Rader* and R. A. Feemster,* Bartlesville, Okla.

(Dallas Meeting, October, 1933)

Because of the necessity for taking regularly occurring open-flow tests in prorated high-pressure oil fields, much gas is turned to atmosphere by way of vertical vent lines leading away from the oil and gas separator. In the past, measurement of such gas has been accomplished by several methods, usually by use of the open-flow Pitot tube. The use of the closed-flow Pitot tube has been avoided apparently chiefly because the ordinary vent-line hook-up makes it necessary to apply the instrument closer to a bend, valve, or obstruction in the pipe than is recommended by rules of good practice.

The many advantages that would result from the application of the closed-flow Pitot tube prompted investigation of the actual effect upon quantity rate of flow measurements computed from data obtained with the tube in a normal working position, which is closer to the tee at the base of the vent riser than is usually considered as giving highly accurate results. An effort was first made to compare the results thus obtained to those under ideal conditions and at high velocities.

To make this comparison, knowledge of the characteristics of gas flowing at very high velocities is essential. Research for such information indicated that little or no work had been done that would give data necessary for such a comparison, therefore the problem was changed to a test designed to determine the relationship between quantity rates of flow as measured by an orifice meter and a Pitot tube placed at the center of a pipe eight diameters from a tee or ell at the base of a vent riser, through which gas is flowing under low pressures at very high velocities.

To determine this relationship, a series of tests was run on a number of 8-in. iron-pipe vent risers in which the Pitot tube data were taken at the position as stated above. Gas from a wet-gas gathering system was passed through an orifice meter setting and thence to atmosphere by way of the vents.

Data were taken simultaneously from the orifice meter and Pitot tube from which computations for comparisons were made. The actual method of comparison is discussed later in this paper.

Since Pitot-tube information is usually given in general terms, and not readily usable, it will be the purpose of this paper to discuss the applica-

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* Engineer with Phillips Petroleum Co.

tion of the closed-flow Pitot tube to the specific problem of measuring high-velocity vent-line gas. This will include information relative to the best type of instrument, method of computation of rates of flow from data obtained by the instrument, and some of the theory upon which computations are based.

Pitot Tube

The Pitot tube (Fig. 1) used in the test was patterned after the one found to give the most accurate data by W. C. Rouse.[1] The unit consists of two concentric tubes, packed off at both ends, containing a 90° bend about 5 in. from the tip. The tip is beveled or "streamlined" so

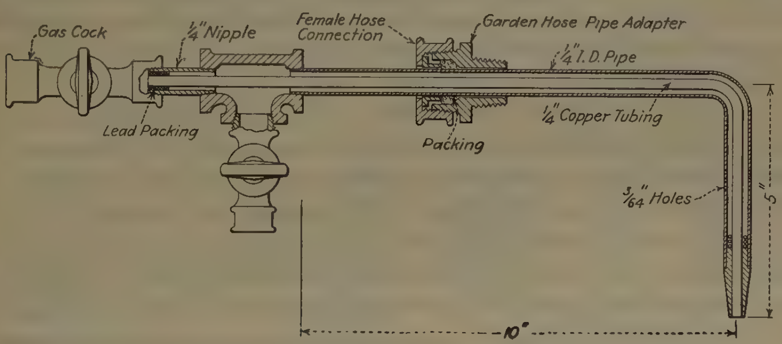

Fig. 1.—Pitot tube used in test.

as to prevent interference with the energy, by the creation of cross currents, etc., when the tube is held in a stream of flowing gas. Midway between the tip and bend are four sets of small holes through the outer tube (two per set), drilled 90° apart on the circumference. By this arrangement, when the tube is held parallel to the stream of flowing gas, the total pressure (sum of the velocity pressure and static pressure), will be transmitted through the center tube and the static pressure alone will be transmitted by way of the small holes in the outer tube and the annular space between the two tubes. The difference of these two pressures is the velocity pressure and from the velocity pressure and static pressure the volume rate of flow can be computed.

Methods of Reading

In previous and other tests, similar to this but with the exception that low velocities were involved, the variation of quantity rate of flow was taken as a direct function of the velocity at the center of the pipe. On the assumption that this is the only factor that enters into the relative

[1] W. C. Rouse: Pitot Tubes for Gas Measurement. *Trans.* Amer. Soc. Mech. Engrs. (1913) **35**.

values of correct rate of flow and that measured by the Pitot tube placed at the center of the vent at such high rates of flow as are considered herein, the ratio of the correct rate to the measured rate will be taken numerically equal to the ratio of the average velocity through the pipe to the center velocity. Since knowledge of the average velocity of flowing gas is necessary for quantity rate of flow computations and the Pitot tube measures only the velocity at the tip of the tube, the following three general methods have been employed in the past to arrive at the average velocity from the Pitot-tube readings:

1. The pipe is traversed with the Pitot tube, taking readings for regular concentric areas. The average velocity head may then be taken as the square of the average of the square roots of these velocity heads.

2. A pressure reading is taken at a point a fraction of the distance from the pipe wall to the pipe center, which is assumed to be the point of average velocity head.

3. The center velocity is measured and the average velocity is computed by the previously determined relationship of the two. For reasons brought out in the following discussion, it is fairly evident that this method is the most adaptable to the problem in question.

W. C. Rouse[2] found that gas flows through a pipe in a wave or spiral motion and at no time is the velocity distributed uniformly across the pipe, being greater in one-quarter section than in the other three-quarters, at which time the velocity on any diameter is constantly changing. However, he also found that there is an approximate relationship between the mean velocity and that obtained by placing the tube at the center of the pipe and for 12-in. ordinary iron pipe, results within 2 per cent may be expected by using

$$v = \sqrt{2g \times 0.8h}$$

in which v is the average velocity and h is the velocity head at the center of the pipe in feet of gas. By taking the 0.8 factor from beneath the radical, the equation becomes $v = 0.895\sqrt{2gh}$ and the 0.895 factor takes on the characteristics of the efficiency factor such as is ordinarily introduced into the orifice meter formula to make the correction from hypothetical to actual flow. In other words, Mr. Rouse found that under ideal conditions at relatively low rates of flow the ratio of the average velocity head to the center velocity head is approximately 0.8, or the ratio of the average velocity to the center velocity is approximately 0.895. It should be remembered that these are the results of tests on a 12-in. pipe under ideal conditions.

Other work has been done relative to the ratios of average to center velocity. The National Physics Laboratory (1914) established a curve

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[2] W. C. Rouse: Reference of footnote 1.

to show this value for given values of $\frac{dv_{max}\gamma}{u}$ in which d = pipe diameter, v_{max} = velocity at center and u is the absolute viscosity. This curve was carried up only through a range of low values of the modulus. An extension of this curve would undoubtedly yield much valuable information concerning the problem herein discussed.

Strictly speaking, this factor is not a constant but increases at higher velocities. The range of variation, however, is so small that the factor

TABLE 1.—*Results for a Typical Vent Line*

Vent No. 1, 8.00 In. Inside Diameter				Vent No. 2, 7.92 In. Inside Diameter			
Metered Volume, Cu. Ft. per Hr.	Velocity Head	Static Head	E	Metered Volume, Cu. Ft. per Hr.	Velocity Head	Static Head	E
	Inches Water				Inches Water		
78,800	0.8	0.9	0.895	111,300	0.60	0.50	1.538
111,300	1.6	1.7	0.895	157,800	2.4	2.3	1.07
176,400	3.4	3.2	0.971	271,100	8.4	7.3	0.98
223,000	6.0	5.2	0.922	315,000	12.4	11.2	0.885
282,000	10.0	8.3	0.898	388,100	18.0	19.2	0.915
313,000	12.2	10.2	0.903	346,000	20.4	28.2	0.95
332,000	14.0	11.7	0.894		Inches Mercury		
398,000	19.4	16.9	0.899				
	Inches Mercury			466,000	2.0	2.1	0.873
				556,000	2.8	2.9	0.898
480,000	2.0	2.2	0.919	595,000	3.2	3.2	0.887
535,000	2.5	3.0	0.890	621,000	3.4	3.3	0.899
571,000	2.7	3.6	0.920	671,000	3.9	3.6	0.902
616,000	3.2	4.2	0.890				
669,000	3.6	4.8	0.895				
710,000	4.2	5.6	0.878				
742,000	4.5	6.0	0.88				

can be assumed to be constant without causing an error in excess of 2 per cent.

As previously stated, lists were made to determine the effect of applying the Pitot tube close to a tee. Evidence of this effect was arrived at by measuring the rate of flow with an orifice meter and at the same time taking the static and velocity pressure with the Pitot tube placed at the pipe center.

As will be brought out later, the quantity rate of flow may be computed from a formula thus:

$$Q = CE\sqrt{h_v p}$$

in which C is a constant for a given set of conditions, Q is the quantity rate of flow, E the efficiency factor, h the velocity head and p the static pressure.

In the test Q was obtained from the orifice meter measurements; C was computed from known conditions of pipe diameter density of gas, etc.; h_v and p were determined by the Pitot tube readings. Solving for E, the results, for a typical vent line, are as given in Table 1, vent No. 1. Vent No. 2 is a good example of inaccuracies that may be met at low rates of flow.

Ordinarily data are obtained with a manometer containing a suitable liquid (usually water or mercury), to register the pressure heads. Because of the fluctuating column of fluid, caused by pulsation of pressure, etc., an error of 1/10 in. could be made easily. This could cause a variation of the E factor as great as any found in Table 1.

From results similar to those in Table 1, it is evident that the approximate ratio of actual flow to theoretical flow remains practically constant at 0.895 over a wide range of velocities, therefore this value will be applied in the following formula to correct the volumes arrived at by the previously stated conditions of measurement.

Formulas

A formula for computing rates of flow from data given by a Pitot tube may be derived as follows in a manner almost identical to that for computing volumes from orifice meter data:

Explanation of Symbols Used

Symbol	Explanation	Unit of Measurement
v	Average velocity of flowing gas	Feet per second
g	Gravitational acceleration (taken as 32.16)	Feet per second per second
d	Diameter of pipe	Inches
P	Absolute pressure of gas	Pounds per square inch
T_f	Absolute temperature of flowing gas	Degrees F.
h	Height of homogeneous column of gas at P and T_f producing v	Feet
h_v	Height of water column corresponding to h (velocity head)	Inches
h_s	Static-pressure head	Inches
γ_w	Density of water taken as 62.37 at 60° F.	Pounds per cubic foot
γ_a	Density of air taken as 0.08073 at 32° F. at 14.7 lb. per sq. in.	Pounds per cubic foot
γ	Density of flowing gas	Pounds per cubic foot
T_b	Absolute temperature base	Degrees F.
P_b	Absolute pressure base	Pounds per square inch
Q	Volume rate of flow	Cubic feet per day
G	Specific gravity of gas relative to air	None
E	Ratio of actual to hypothetical flow	None
A	Area of cross-section of pipe	Square foot

Subscripts: b = base, f = flowing, a = air, s = static pressure, w = water.

Quantity rate of flow is determined by area times velocity rate of flow, or

$$Q = 86{,}400\ Av.\ \text{cu. ft. per day} \tag{1}$$

If a column of gas is enclosed in a vertical pipe and the bottom of the pipe is opened, the gas will flow from the pipe with a velocity according to the fundamental law

$$v = \sqrt{2gh} \tag{2}$$

If this same column of gas is supported by the pressure due to the velocity of a moving body of gas, it can be assumed that the gas is moving with the velocity v where

$$v = \sqrt{2gh}$$

Since it is inconvenient actually to measure a head of gas, its equivalent of a liquid may be substituted. If water is used, and measurements are in inches, the change must be made as follows:

$$h = \frac{h_v \gamma_w}{12\gamma} \tag{3}$$

Substituting for h_v

$$v = \sqrt{2g\frac{h\gamma_w}{12\gamma}} \tag{4}$$

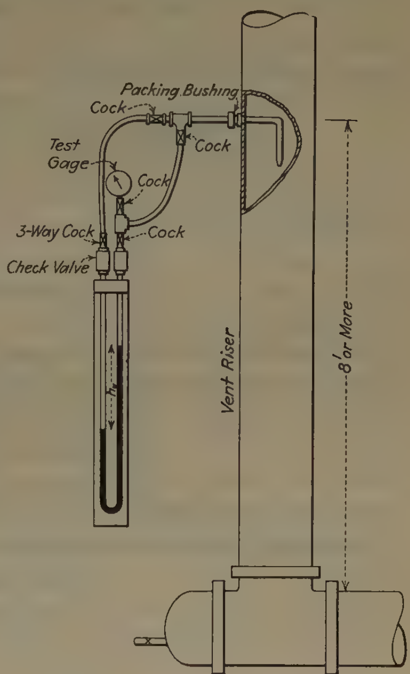

FIG. 2.—PITOT TUBE ON VENT.

The density of a gas is equal to the product of the density of air and the specific gravity of the gas, each at the same temperature and pressure conditions. The density of air at 32° F. and 14.7 lb. per sq. in. is 0.08073 lb. per cu. ft. Since the density of a gas varies directly as the absolute pressure it exerts and inversely as the absolute temperature, the density of gas at any temperature and pressure conditions is

$$\gamma = G \times 0.08073 \times \frac{P_f}{14.7} \times \frac{49.2}{T_f} \tag{5}$$

Substituting in formula 4 for γ, g and γ_w

$$v = \sqrt{\frac{2 \times 32.16 \times 62.37 \times 14.7 \times h_v T_f}{12 \times 0.08073 \times 492 \times P_f G}}$$

Then substituting for A and v in equation 1

$$Q_f = \frac{86{,}400\pi d^2}{4 \times 144}\sqrt{\frac{2 \times 32.16 \times 62.37 \times 14.7 \times h_v \times T_f}{12 \times 0.08073 \times 492 \times PG}} \tag{6}$$

This equation gives the quantity, in cubic feet per day, flowing at the temperature and pressure conditions of the flowing gas. To refer this to some temperature and pressure base, the following factors are introduced: By a law of gases (combination of Charles' and Boyles' laws),

$$\frac{P_f Q_f}{T_f} = \frac{P_b Q_b}{T_b};\ \text{hence } Q_b = \frac{P_f Q_f T_b}{T_f\ P_b}$$

Then replacing Q_f by the right-hand member of equation 6,

$$Q_b = \frac{86{,}400\pi d^2}{4 \times 144}\ \frac{P_f T_b}{T_f P_b}\sqrt{\frac{2 \times 32.16 \times 63.37 \times 14.7 h_v T_f}{12 \times 0.08073 \times 492\ P_f G}} \qquad [7]$$

Clearing and canceling, $\dfrac{T_f}{P_f}$

$$Q = 5242.56 d^2 \frac{T_b}{P_b}\sqrt{\frac{h_v P}{T_f G}} \qquad [8]$$

For reasons previously brought out, the efficiency factor must be introduced into the equation, thus giving the formula

$$Q_b = 5242.56 E d^2 \frac{T_b}{P_b}\sqrt{\frac{h_v P}{T_f G}} \qquad [9]$$

which is the basic formula to which any set of conditions may be applied.

Gas-measuring practice generally assumes the following conditions:

$$T_b = 520° \text{ (60° F.)}$$
$$T_f = 520° \text{ (80° F.)}$$
$$P_b = 14.4$$
$$G = 1$$

Substituting these conditions in formula 9, we find that

$$Q_b = 8301.08 E d^2 \sqrt{h_v P} \qquad [10]$$

Where both h and P in equation 10 are measured in inches of water, and $E = 0.895$, we find:

$$Q_b = 1411.66 d^2 \sqrt{h_v(408 + hs)} \qquad [10a]$$

When both static and velocity pressures are measured in inches of mercury, equation 10 becomes

$$Q_b = 19{,}361 d^2 \sqrt{h_{v\mathrm{Hg}}(30 + h_{s\mathrm{Hg}})} \qquad [10b]$$

These equations assume atmospheric pressure to be 14.7 pounds per square inch.

It has been demonstrated in the field, by the writers, that formula 10*b* is applicable to data obtained by the closed-flow Pitot tube for volume rates of flow between 2,000,000 and 17,000,000 cu. ft. per day through an

8-in. vent line. It is reasonable to believe that the general formula would hold true for vent lines of other diameters and at higher rates.

Conclusion

This discussion brings out the fact that the closed-flow Pitot tube can be used under conditions considered adverse to good Pitot-tube practice, with a comparatively high degree of efficiency. It may be that the same efficiency factor as determined herein would not hold true for all sizes of vents, but it is reasonable to believe that for pipes of sizes used for vent risers the value of the factor would not vary appreciably.

It should be noted that the value of the E factor as determined by W. C. Rouse for velocities up to 100 ft. per second arrived at under ideal flow conditions coincides with that obtained at very high velocities (800 ft. per second and over) obtained close to a bend. It may be that at the high velocities, the bend does not have so great an effect as at low velocities and the relationship as established by Mr. Rouse can be extrapolated to apply to higher velocities.

The increased demand for more knowledge concerning limits of application of the closed-flow Pitot tube to vent-line gas measurement should justify further investigation into the subject.

The information most useful for the application of the Pitot tube as herein described would be in the form of data concerning the effect as reflected upon the efficiency factor by varying the velocity up to critical velocity through pipes of various diameters.

Until this is done, however, the relationship established herein can be used with the assurance that it yields more consistently accurate results than that provided for other types of Pitot tube.

In addition to the paper by W. C. Rouse, the authors consulted a paper by T. B. Weymouth, on National Gas Measurement, and various textbooks.

DISCUSSION

(E. A. Stephenson presiding)

C. M. Rader.—It was early seen that all the various operating companies should be in a position to measure gas on the same basis. We found many different methods in use and they varied in results obtained up to a maximum of 30 to 40 per cent. If oil production is to be prorated on a gas-oil ratio basis it is advisable to have an accurate system for measuring the gas.

L. J. Pepperberg,* Dallas, Tex.—If accurate methods for measurement of gas are employed as gas wells are drilled in we will have valuable data upon which to base the estimated thickness of the "pay" portion of the producing formation.

* Consulting Geologist and Engineer.

Comparative Resistance of Certain Commercial Ferrous Materials to Corrosion by Gaseous Hydrogen Sulfide*

(A Laboratory Study at Ordinary Temperatures)

By John M. Devine,† C. J. Wilhelm‡ and Ludwig Schmidt,§ Bartlesville, Okla.

(New York Meeting, February, 1934)

Abstract

A corrosion-testing apparatus which operates in the field and which will determine the comparative resistance of various ferrous materials to corrosion by gaseous hydrogen sulfide at ordinary temperatures is described. The principle of the uniform method of testing is to allow natural gas containing hydrogen sulfide, direct from its source in the field, to flow over the group of specimens for a given period of time, and subsequently to estimate the corrosion sustained by each specimen by determining its loss in weight. The comparative results obtained when specimens of 47 representative ferrous materials of described typical composition were tested at ordinary temperatures with natural gas containing hydrogen sulfide are given in tables showing average penetration of metal, inches per year.

The primary purpose of the work was to determine the possible utility to the petroleum and natural gas industries of ferrous materials that are commercially available, and no attempt is made to discuss the results of the tests from the metallurgical standpoint. The following is a summary of the results obtained:

1. Steels containing 12 to 27 per cent of chromium showed the highest resistance to corrosion. The presence of nickel in these high-chromium steels did not affect their resistance.

2. Steels containing approximately 5 per cent of chromium showed comparatively high resistance, but somewhat less than that of the high-chromium steels.

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* Printed by permission of the Director, U. S. Bureau of Mines. The paper in full was published as A.I.M.E. *Tech. Pub.* 531.

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3. Nickel cast iron was indicated as having resistance superior to all other materials tested, except those mentioned in paragraphs 1 and 2.

4. The remaining materials tested were attacked comparatively rapidly. These may be divided, however, into a "more resistant group" and a "less resistant group," as follows:

(*a*) More resistant group: steels containing 0.50 to 5.00 per cent of nickel; copper-molybdenum steel; steels containing 0.65 to 1.00 per cent of chromium; copper-bearing steel; electric-furnace iron; and wrought iron (hand-puddled).

(*b*) Less-resistant group: ordinary bessemer and open-hearth steels; medium carbon steels; wrought irons; plain cast iron; and steel containing 2 per cent of silicon.

DISCUSSION

(*K. B. Nowels presiding*)

[This discussion refers to the original paper. See footnote on page 106.]

R. A. Cattell,* Washington, D. C., in presenting the paper, stated that it was the third of a series and referred to the earlier work of the authors[1] which gave the foundation for the present study. A particular application of the whole study is to the problem of internal corrosion of natural gas transmission lines.

Referring to the results given in the conventional terms: "average penetration of metal, inches per year," Mr. Cattell explained that these figures were obtained by multiplying loss in weight by suitable numerical factors, as described by Speller,[2] and that this designation of the corrosion effect upon the subject metal gives a method of comparison, or "measuring stick," that is independent of the size and shape of the specimens.

Replying to the comment of a member that the accelerating effect of salt water may be in contrast with the humidity conditions of the tests, Mr. Cattell stressed the point made by the authors that such small-scale corrosion tests were indicatory only and that ultimate conclusions must be contingent upon trial under actual field conditions; where, in every instance, consideration must be given to economic as well as technical factors. Although recognizing their value, duplicate specimens were not used in the reported work because of limitations on time and facilities. However, a number of the specimens tested in the first run were also tested in the second, and consistent results obtained. The uniform method of testing is subject to reproducibility which would be difficult if brines had been employed to keep the metal surfaces in a wetted condition. Mr. Cattell emphasized the desirability of further work on the problem.

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* Chief Engineer, Petroleum and Natural Gas Division, U. S. Bureau of Mines.

[1] J. M. Devine, C. J. Wilhelm and L. Schmidt: The Effect of Oxygen on Gaseous Hydrogen-Sulfide Corrosion of Tank Steel. U. S. Bur. Mines *Rept. of Investigations* 3160 (1932).

Corrosion of Steel by Gases Containing Traces of Hydrogen Sulphide; Effect of Pressure and Moisture Conditions. U. S. Bur. Mines *Tech. Paper* 560 (1933).

[2] F. N. Speller: Corrosion—Causes and Prevention, 580. New York, 1926. McGraw-Hill Book Co.

The discussion of the influence of brines upon the corrosion effect turned to the recently revived method of stimulating oil (and gas) production by acid treatment. As an example of a number of conflicting problems having their origin in this stimulative method, a member cited experiences which seemed to indicate that certain inhibitors had failed to prevent corrosive action on well equipment in some fields where hydrogen sulfide and salt water were present.

O. B. J. Fraser,* Bayonne, N. J., made the following technical comments (written):

1. Ideas as to why the metals had not aligned themselves according to their relative position in the electromotive series would be helpful.

2. In reference to test procedure, the clothing of the test pieces with wet muslin sacks raises a question as to the influence of the wet fabric on the course of corrosion. It would be expected, in many cases, that this would cause some acceleration of corrosion due to concentration-cell reactions consequent upon concentration gradients of important corrosive components of the liquid film due to shielding effects of the fabric. Such effects, if they occurred at all in the authors' experiments, would occur on materials containing little or no chromium, the high-chromium alloys being less subject to them.

3. Usually, in corrosion testing, it would be considered an error in procedure to set specimens one above the other, so that moisture-carrying soluble products might drop from the upper specimens to those beneath. In the present tests, this condition may have been of no consequence, but in other cases the quantitative figures would have doubtful utility.

4. The authors prepared their test pieces by somewhat refined methods of polishing, which would be expected to produce on a high-chromium alloy a surface condition highly inhibitive to corrosion. The influence of high surface finish would not be so great in lowering the normal corrosion rate of the other materials.

5. The test period of 24 hr. possibly was too short to give a complete picture for the particular type of corrosion involved. Discussion of the possible influence of a longer period upon the results given in the tables would be helpful.

6. The possibility of significant amounts of metal being removed in final polishing of the corroded specimens is suggested. As the corrosion products were loosely adherent, presumably but little pressure was required for their removal. As the total loss in weight of the individual test pieces was small, if any metal was abraded in the final cleaning note should be taken of this condition.

7. Treating the subject of the accelerating effect of salt water, discussed at the meeting and mentioned in the summary of oral discussion, Mr. Fraser also referred to the destructive influence of chlorides upon what otherwise would be protective films of corrosion products and thought dangerous even a qualified suggestion that the results may have a limited application to hydrogen sulfide corrosion in which salt water is present.

8. Commenting on the authors' statement that the presence of nickel in chromium steels did not appear to impair their resistance to corrosion, which is in contrast to the conclusions of White and Marek,[3] Mr. Fraser said: "Their tests were made on forging steels at forging furnace temperatures which is extremely far removed from the field covered by the present paper."

9. Where reference is made to nickel cast iron in tables and text, it would be advisable to call this material "nickel-copper-chromium cast iron" because it has significant amounts of both copper and chromium as well as of nickel.

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* Research Metallurgist, International Nickel Co.

[3] A. White and L. F. Marek: Corrosion of Mild Steel and Alloys by Hydrogen Sulphide at 500° C. and Atmospheric Pressure. *Ind. & Eng. Chem.* (1932) **24,** 861.

10. Although conditions of pressure and hydrogen sulfide content were not exactly the same in the two runs, yet they were sufficiently close so that the runs might be considered as varying from each other principally as to temperature. This makes it possible to draw conclusions on the effect of temperature upon the corrosion of several materials that were tested in both runs.

11. In reference to item 1, summary of results, it is reasonable to assume that any material with more than 27 per cent chromium would continue to show zero corrosion under the given test conditions.

Mr. Fraser, in transmitting his comments on the paper, said: "It furnishes some timely information in a field of corrosion which has received scant attention up to the present."

L. Schmidt (written discussion).—Mr. Fraser's very able and complete discussion of this report has brought out several pertinent facts. Unfortunately, however, several of his questions cannot be answered at this time, for, as pointed out by Mr. Cattell, "These small-scale corrosion tests are indicatory only and ultimate conclusions must be contingent on trial under actual field conditions."

There are several different classifications of corrosion and although this particular type of modified gaseous corrosion has been classified as electrochemical corrosion, there is good indication that it is a combination of chemical and electrochemical corrosion, which may account for the fact that metals do not align themselves according to their relative position in the electromotive series.

In reference to the test procedure, the specimens were covered with wet muslin sacks to keep a moisture film over the entire surface of the test specimen, thus duplicating field conditions as far as possible. Where sufficient corrosion has taken place under service conditions, scale formed on the surface of the exposed metal will set up oxygen concentration cells, and the writers believe that by the use of muslin sacks a similar condition was created. There was no evidence in the tests that corrosion products dropped from top specimens to lower ones.

The writers agree with Mr. Fraser that probably the influence of the polished surface in preparing the test specimens tended to make the high-chromium alloys more inhibitive to corrosion than some of the other metals. The method used, however, was adopted in order to use the loss-in-weight method for determining the amount of corrosion that occurred. The corrosion products were readily removed from the test specimens without perceptible loss of the metal. For example, check runs made on blank specimens showed that the maximum loss in weight of metal was less than 0.1 mg. for the softest specimen.

In regard to the influence of a longer period of testing upon the results, previous laboratory tests[3] of 72-hr. periods indicate the rate of gaseous hydrogen sulfide corrosion to be a straight-line function of time. However, it is a recognized fact that, as products of corrosion are formed, the rate of corrosion varies. The work of the writers indicates that these data may have a limited application to hydrogen sulfide corrosion where salt water is present; however, it must be kept in mind that this study is preliminary, and much additional work is necessary before definite conclusions may be drawn.

M. H. Clark,* Reading, Pa. (written discussion).—The authors are to be complimented upon their choice of an important and interesting subject for investigation and the attention given to details of the apparatus and the conduct of the tests. However,

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[3] J. M. Devine, C. J. Wilhelm and L. Schmidt: The Effect of Oxygen on Gaseous Hydrogen Sulphide Corrosion of Tank Steel. U. S. Bur. Mines *Repts. of Investigations* 3160 (1932) 14.

* Vice President, Reading Iron Co.

laboratory corrosion tests under controlled conditions have little, if any, practical value because of the difficulty of reproducing in the laboratory the actual conditions encountered in service. The authors recognize the limitations of laboratory tests when they say: "It must be emphasized, of course, that such small-scale corrosion tests are indicatory only; ultimate conclusions regarding the comparative resistance of any material will always be contingent upon its trial under actual field conditions."

Under actual service conditions tanks, pipe, sucker rods, wire cable and other ferrous materials are rapidly and seriously attacked, generally by a pitting type of corrosion. Furthermore, sucker rods and wire cable that are subjected to alternating stresses are seriously embrittled by hydrogen sulfide and the life of such parts is reduced out of all proportion to the visual damage. It is an established fact that hydrogen sulfide gas alone will not attack iron and steel, but in conjunction with oxygen and water it is responsible for some of the most serious corrosion problems of the oil producer. All three of these agents are essential. It is a common belief that a high concentration of hydrogen sulfide is necessarily the cause of rapid corrosion. This is a misapprehension. If both air and water are not present, hydrogen sulfide is not corrosive. (Hydrogen sulfide gas, under pressure, is handled in steel containers without corrosion.)

This work evidently did not cover the effect of varying oxygen content of the gas. This also raises the question of the position of the samples in the apparatus in relation to the gas inlet. Let us say that during the first experiment sample A is placed at the top of the apparatus. In this position it is at the gas outlet. If the water in the humidifying tower has not been boiled to remove dissolved oxygen and carbon dioxide, this sample on inspection may not show signs of any attack whatsoever. If, on the other hand, this is placed in the bottom of the apparatus, adjacent to the gas inlet, where it receives the full benefit of the dissolved oxygen and carbon dioxide in combination with the gas containing hydrogen sulfide and it again does not show signs of attack, we can conclude that it is resistant to gases containing hydrogen sulfide.

In addition to the location of the sample with respect to incoming gas stream and oxygen concentration, we have another variable to consider—time. Does the attack accelerate or decelerate as the time interval increases?

For these reasons the classification of materials in the order of their excellence on the basis of a uniform loss of weight as determined by a laboratory test (Tables 2 and 3) is likely to lead to false conclusions regarding the resistance of the more commonly used materials to attack by hydrogen sulfide.

Moreover, regardless of the practical application of Tables 2 and 3, the figures that govern the classification of the specimens in these tables are based on the results of a test of only 24-hr. duration. The calculated penetration per year "on the specimen most seriously attacked is but 0.0454," which indicates that the total loss in weight of the laboratory specimens must have been very small indeed. Results of short-time tests are apt to be misleading, particularly where the differences between individual samples are as small as they must have been in this case.

In my opinion, preliminary data of this kind are likely to be of a distinct disadvantage if taken seriously.

Chapter II. Petroleum Economics

An Aspect of the Arbitrary Restraint of Production

By John D. Gill,* Philadelphia, Pa.

(New York Meeting, February, 1934)

Restriction programs in important raw-materials industries in foreign countries have been abandoned after lengthy trials. Presumably, failure has been a logical consequence of the attainment of objectives of the restrictive schemes in the early periods of their administration in defiance of economic law. In general, the chief objective has been the elevation of prices of the products of these industries. More conservative plans have sought the maintenance of a price structure that was in jeopardy at the time restriction was initiated. The course of the administration of restrictive measures can be traced by the results of restriction, viz.: the creation or maintenance of highly profitable prices; the overexpansion of productive facilities; the accumulation of inventory; and finally, by the collapse of the price structure, which invariably has led to abandonment of the restrictive scheme. The theory and practice of restriction as applied to industries that have tried it are too well known to need detailing here.

Restraint of Production of Crude Oil

Regardless of the record of the catastrophic outcomes of restrictive measures in other industries, our industry has not been deterred from attempting restriction of crude-oil production. The assumed bases for success of our restrictive plan are clear. They follow from the fact that the physical characteristics of the petroleum industry differ from those of other industries that have tried restriction. Its raw material is a highly essential substance, a natural, exhaustible resource. The extent of its reserves is unknown, a fact that arouses the cooperative spirit of conservationists. At no time before the inauguration of restriction had its developed reserves been sufficient to supply more than the requirements for a few months without the help of new drillings. To a considerable extent its discovery involves the element of chance. Its economic production seems to require an unnatural relationship; namely, cooperation among competitors, because it is a fugitive resource, capable of moving from under one owner's property to underlie another's. Thus its recovery presents intricate legal questions concerning property rights.

* The Atlantic Refining Co.

The characteristic underground behavior of the petroleum resource and its associated fluids has presented large and nearly insoluble engineering problems, which experts have contended could be solved only by the enforcement of the arbitrary restrictive measures. Indeed, these legal and engineering problems have obscured the basic economic problems involved in restriction so that the latter have received at most but superficial consideration. Finally, the crude-petroleum industry differs from other basic mineral industries also in this important particular: under economic freedom the return of 90 per cent of the capital investment may be effected in a comparatively short time—approximately six years.

Generally, programs for the arbitrary restriction of output have been predicated upon a condition of overproduction. In this respect

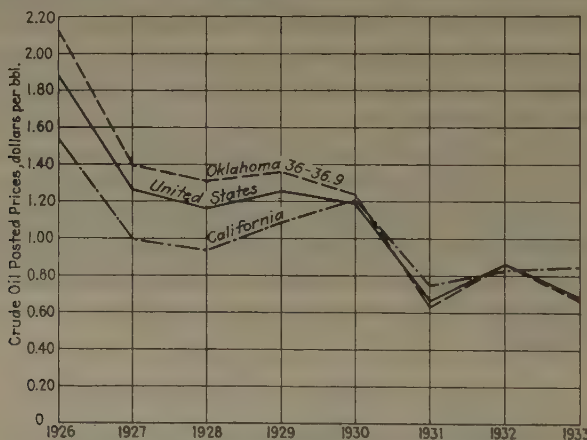

FIG. 1.—POSTED PRICES OF CRUDE OIL.

oil restriction has a family resemblance to other restrictive schemes. But petroleum restriction has been supported also upon a platform of extenuating circumstances, mostly of a technical and legal, rather than economic, character, making that which had been proved uneconomic in other industries seem to be economic in ours. Indeed, facts can be presented to make it appear that during most of the period of restriction the affairs of the petroleum industry have been conducted along strictly economic lines. Examine these indicators of apparent economic orthodoxy.

In the first place, restriction of crude-oil production cannot be said to have raised prices above the prices of the prerestriction period; or even to have stabilized prices at levels existent at the time curtailment was initiated. As a matter of record, the prices of crude petroleum have been continuously under the level of prices of the first full year of the attempted administration of industry-wide restriction plans. On the whole,

prices have declined during the period of restriction, especially during the last three years, when the restrictive administration was effectively organized. This fact is illustrated by Fig. 1, which shows the average annual posted well prices of crude oil throughout the United States during the period under consideration.

In the second place, while other restrictive adventures have been proved uneconomic by the ultimate effects of the creation of a superfluity of productive facilities, which were motivated by the profitability of the artificially maintained price structures, the petroleum industry appears actually to have reduced greatly its efforts to create new production

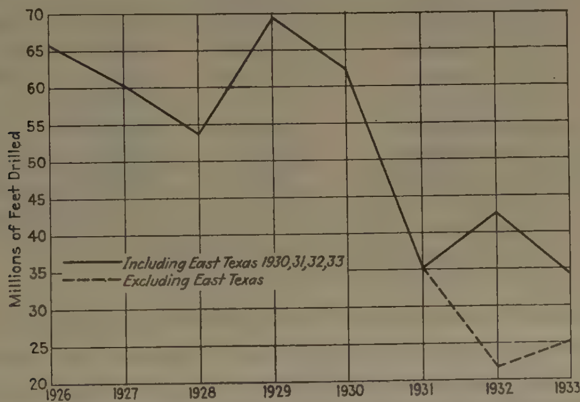

FIG. 2.—OIL-FIELD DEVELOPMENT IN THE UNITED STATES.

facilities, especially during the last three years of effectively administered curtailment. Such a conclusion might be drawn from the statistical facts presented in Fig. 2, which shows, in terms of feet of well drilled, the effort to develop oil leases; and by the facts in Table 1, which presents the number of wells actually completed annually during the eight-year period that began just before the organization of arbitrary restriction.

TABLE 1.—*Oil-well Completions in the United States*

YEAR	TOTAL COMPLETIONS	COMPLETIONS EXCLUDING EAST TEXAS	YEAR	TOTAL COMPLETIONS	COMPLETIONS EXCLUDING EAST TEXAS
1926	29,319	29,319	1930	21,232	21,217
1927	24,143	24,143	1931	12,351	8,955
1928	22,331	22,331	1932	15,021	9,261
1929	26,356	26,356	1933	12,312	9,845

Finally, also suggestive of the operation of the same free economic forces that effected ups and downs in the supply-demand ratios during the prerestriction period, is the record of similar ups and downs during the period of curtailment. The restrictive plans of other industries have led to the production of burdensome accumulations of product. By contrast, so far, crude-oil restriction has effected a reduction of the

inventory to a level below that existent at the time restriction was begun. These facts are shown in Table 2, which presents the end-of-the-year levels of crude-oil inventory and the relation, annually, between supply and demand.

TABLE 2.—*Relation of Demand to Supply of Crude Oil in the United States*

Year	Ratio Total Demand to Total Supply	Total Stocks End of Year,[a] Thousands of Barrels	
1926	1.033 undersupply	402,299	
1927	0.926 oversupply	473,379	Restriction conceived
1928	0.977 oversupply	490,788	Restriction not effective
1929	0.959 oversupply	540,851	Restriction partially effective
1930	1.022 undersupply	516,424	Restriction effective
1931	1.058 undersupply	468,681	Restriction drastic
1932	1.117 undersupply	438,454	Restriction drastic
1933	0.996 balanced supply	446,755	Restriction efforts meeting renewed opposition

[a] For comparability, includes fuel oils in California.

Summarizing the evidence of the apparent economic conduct of the producing division of the business during the second half of the period of restricted output: actual overproduction was prevented; prices did not rise, but declined; and *efforts* to expand productive facilities actually contracted to below average levels which heretofore had been found necessary for the satisfaction of demand.

The existence of production engineering problems, concerning the maintenance of reservoir pressures for the purpose of increasing ultimate recovery, the reduction of operating costs, and the avoidance of economic waste by a process of rational well spacing, is a matter of record. No doubt, in pools of divided ownership such problems can be solved only by cooperative measures, which restrict the freedom of the individual unit. Nevertheless, I submit that the extent of restriction has exceeded that necessary to the advance of production technique; and further, that if such uneconomic and arbitrary restriction of production is continued indefinitely the ultimate outcome will not differ greatly, in character, from the conclusions of the restrictive schemes of other industries.

ECONOMICS OF RESTRICTION OF PETROLEUM

It would be remarkable indeed if, in the light of the failures of other industries arbitrarily to restrict production, the oil industry could conduct indefinitely a restriction program satisfactory to producers and consumers alike. I believe it cannot do so. However, I shall not take

the time to discuss the universal features of a restriction program that disclose the bases for its essentially uneconomic character. Beyond question, it can be demonstrated that the arbitrary restriction of output is incompatible with the highest material welfare of all the people. Arbitrary restriction implies a lower total of production and distribution of all goods and services than is physically possible and socially desirable. In the petroleum industry, restriction also diverts human energy from the production and enjoyment of consumable goods to the creation prematurely of capital goods, which in all probability could be produced more efficiently at a later time. It stifles initiative, which is requisite to progress and which heretofore has been valued highly by petroleum

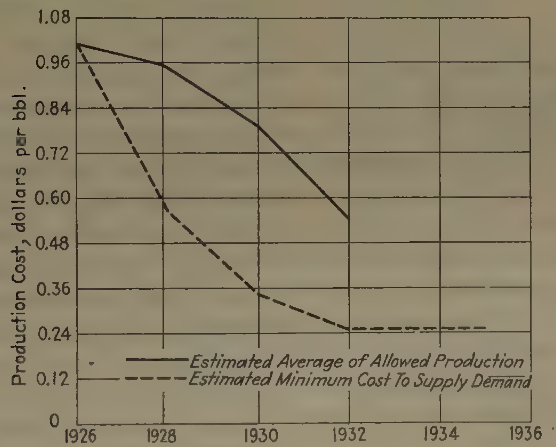

FIG. 3.—PRODUCTION COSTS OF CRUDE OIL UNDER CURTAILMENT OF OUTPUT.

producers and consumers. Nor shall I more than mention and briefly illustrate the facts that under a program of arbitrary restriction of production the oil that is hardest to produce and to carry to market is accorded freedom of the market at least on equal terms with the oil that is the easiest to produce and to transport, and that the most efficient operators are restrained as much as, or more than, the less efficient.

Consider for another moment the last mentioned phase of the matter, because it illustrates the economics of the restriction of petroleum. Presumably, there would be no restriction if overproduction did not threaten. The cheapest production is restrained as much as, or more than, the dearest. Patently, the result of restriction is to cause the average unit cost of the allowed production to exceed the unit cost of the cheapest production capable of satisfying demand.

The relation between the actual unit cost of allowed production and the unit cost of the same volume of the lowest-cost production is presented

graphically by the lines of Fig. 3, which show a composite of estimates of the unit costs of twenty-odd producing companies of which production has been restricted in common with that of all other producers, and estimates of the average unit costs to produce from the lowest-cost operations enough crude oil to fill demand. The last named line has been projected into the future on the basis of estimated results shown in Fig. 5.

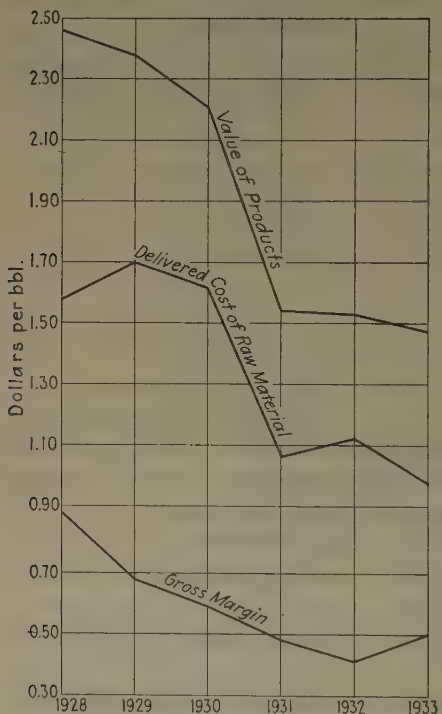

Fig. 4.—Refinery gross unit margins, being the difference between the value of products and the cost of raw materials.

If there were a place in this paper for a discussion of the effects of restriction upon the ultimate consumer of petroleum products, it would follow naturally the presentation of Fig. 3. The lines suggest that our industry is following an uneconomic course, not more tenable than would be the course of an agricultural community that cleared its lands of timber, tilled first the poorer lands, and held the most fertile lands in reserve for some possible future need. In this connection it is not to be forgotten that the rapidity of the growth of our national economic welfare has been predicated upon the usage first of the best things available. However, this aspect of restriction is worthy of separate consideration and is outside the scope of this article. We are concerned here primarily with the effects of restriction upon the members of our own industry, and especially with the prospective effects of a continuance of existing restrictive measures.

The increasingly difficult and insecure position of the nonintegrated refiner is worthy of notice. During the past five years of tumultuous activity for the creation and maintenance of restrictive measures, the annual gross unit operating margin accorded the refining division of the industry has contracted markedly. Some marginal decline was to be expected. It came as the inevitable and proper result of the decrease in refinery operating expenses; notably, for labor, fuel, and supplies. However, the actual shrinkage in refinery gross margins, as indicated by the lowest line of Fig. 4, has been of a magnitude significantly exceeding

the decline in manufacturing costs. The annual gross unit margins shown on Fig. 4 represent the differences between the estimated refinery value of the products derived from a barrel of raw materials and the delivered cost of the latter, including crude oil at posted prices. Out of the gross margin the refiner must pay all expenses and fixed charges. What remains is profit on refinery investment. It is safe to say that during most of the months since the middle of 1929 the refining units that have been charged posted prices for crude run to stills have not earned an average return on investment; and that in many of the months the gross margins have been insufficient to cover even operating expenses and fixed charges. That this aspect of restriction has not been without its hardships is evidenced by the mortality of units specializing in refining.

In self-defense some of these nonintegrated units have been forced to become producers of crude oil. Moreover, and of even greater significance, partly integrated refiners have been compelled to enlarge production activities. Thus, in a roundabout way, restriction has increased competition among producers, has tended to increase potential overproduction and, by a paradox characteristic of uneconomic ventures, has brought about the need for more restriction. Hereafter, mention will be made of the process by which restriction, by increasing the length of time necessary to the recovery of production-capital, increases the amount of capital required per barrel of oil produced and so tends to discourage production by units possessed of small capital resources. The point here worthy of note is that the places of those so deterred will be taken by the more resourceful units mentioned above, which must enter, or extend operations in, the division of production for the protection of their interests in other divisions of the industry.

It has been shown how refiners, caught between low product realizations and relatively high crude costs, as results of arbitrary restriction, have been compelled to adopt a policy which in the long run may prove inimical to investors in production. The ultimate outcome will depend on conditions that no man can foresee. The two primary possibilities should be examined.

First, circumstances may develop surrounding the supply of, and demand for, crude oil that will cause every producer to derive satisfaction from his contribution to the curtailment enforcement of the past several years. Within a few years to come the industry may face a real shortage of oil. Demand may tend to attain progressively higher levels. Discovery of reserves may proceed at a slower rate than the rate of growth of demand. All existing pools may be fully developed. Suitable commercial substitutes for crude or its products may not be available. Obviously, under such conditions there would be need for every last barrel recoverable from known reserves. Even the utmost production possible from the currently operated 275-odd thousand small or "strip-

per" wells, the saving of whose tapped reserves has supplied a basis by which to rationalize restriction, may be required to supply the need. The average age of these wells is upwards of 21 years. They reach into sands of which recoverable reserves originally totaled possibly six billion barrels. Probably they have produced more than 95 per cent of the oil recoverable in the present state of the art. At most they cannot be expected to produce more than four or five hundred million barrels more—a quantity less than our import barriers will shut out in the next few years. But even this quantity may be needed and the industry and the public will be glad that stripper wells have been saved.

Under these conditions the administration of restrictive measures probably would benefit proportionately all producers, whether high-cost or low-cost. Nor would any producer have to surrender any special advantage that accrued to him from the enforcement of restriction during the period of potential oversupply. To some this is indeed not an unpleasant prospect. Moreover, it may eventuate. But clearly it is only one way of looking at the matter. Consider the prospective results of restriction during a future supplied bountifully with petroleum or an acceptable substitute therefor.

Suppose that the discovery of reserves will be made at a rate exceeding the rate of growth of demand; that demand will dwindle; that competitive substitutes for petroleum products will be synthesized commercially. Further, that natural resources of related hydrocarbons will be made commercially available. For example, that shale-oil production costs will decline below "scarcity" crude costs, thus making available the 108 billion barrels of shale oil which, nearly 10 years ago, the Committee of Eleven said could be obtained from oil shales in the United States. Suppose that the hydrogenation of coal, which, it is reported, under the protection of import duties is proceeding abroad at an increasing rate and with alleged yields corresponding, in this country, to a coal cost of less than 1.5¢ per gallon of motor fuel, should become highly competitive with production of crude oil. Such competition is not imminent, but we are concerned here with the ultimate outcome of the long-continued restriction of production facilities, a large fraction of whose investment under present plans will not be written off until after the lapse of 30 or more years from the date of installation. Time may bring many changes.

At present the provisions of the restriction program provide for the complete freedom of many of the so-called stripper wells and for varying degrees of curtailment up to 95 per cent of capacity of wells in the most prolific flush pools. The weighted average restriction is of the order of 85 per cent of productive capacity. But even such drastic restriction would be insufficient to maintain a predetermined price level, or a price level that would assure a satisfactory return on most existing production

investment, if the industry should experience the realization of the last mentioned set of possible conditions. More and more restriction would be required to maintain a satisfactory price level. Parenthetically, restriction, regardless of price, is not required for the purpose of maintaining supply equal to demand, because demand is a function of price, and in the long run would match supply in a free market.

Under conditions of an abundant supply, what would be the profitability of the investment of properties that would have to carry very

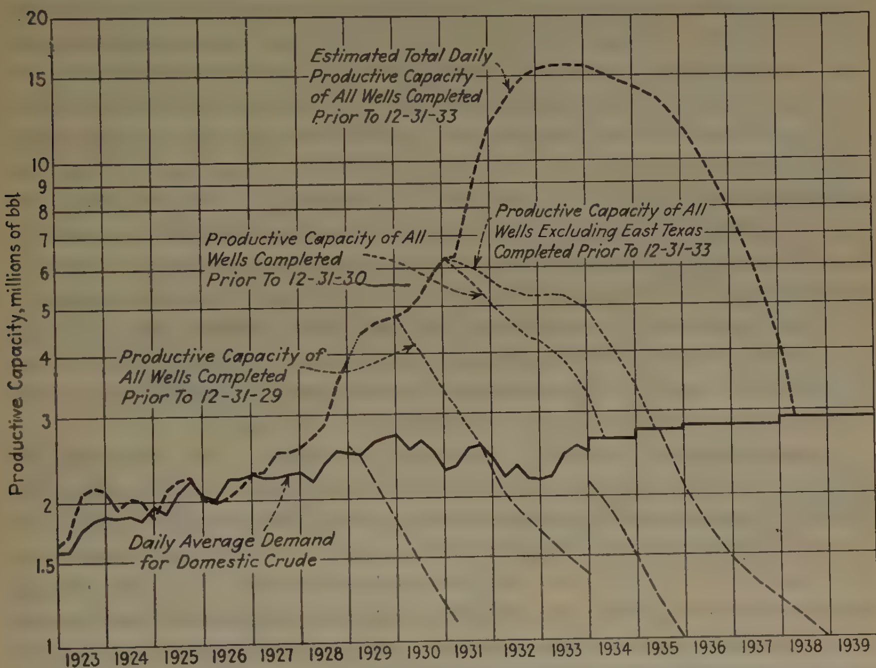

FIG. 5.—PRODUCTIVE CAPACITY OF OIL-FIELD DEVELOPMENTS.
Showing actual and prospective demand for domestic crude. Estimated potential production of domestic crude. Estimated ability of developments with and without East Texas to supply demand without aid of additional developments, as of end of 1929, 1930 and 1933.

heavy deferment charges? What would be the effect on those who bought and developed properties with borrowed money and whose incomes under the more and more severe restrictive measures did not meet fixed charges? And would properties lost to their original owners by foreclosure proceedings be decapitalized and thus enabled to compete successfully with even the lowest-cost fully capitalized facilities?

Speculative Feature

It is this aspect of the subject that I would especially emphasize; namely, its speculative and therefore uneconomic feature. Restriction in the present is predicated on the hope that the existing dollar-values

of developed reserves and undeveloped leases may be maintained through scarcity of the resource, which is expected to result from the combination of enlarged demand and the failure to discover resources commensurate with that demand. What warrant has our industry for basing a restriction program on such an assumption? Behind us is three-quarters of a century of discovery at an accelerating rate, with the last four years contributing an excess far beyond current visible needs. Indeed, the developed resources of the industry at this time project our national potential supply further into the future than at any time in the history of the industry. This statement is illustrated by Fig. 5, which indicates that the country's prospective requirements for crude petroleum to the middle of 1938 could be supplied by wells drilled prior to the end of 1933.

Considering the nature and uses of petroleum and the small proportion of the total supply that can be controlled by any operator, it is as much the part of wisdom to assume the existence of reserves ample for years to come as it is to speculate on a prospective shortage, because, in the latter event, it makes little material difference whether the supply is depleted in 10 years or in 12 years. Those who hold the reserves last to be lifted may receive high prices for them, and thereby may obtain a high rate of return on their residual investment; but probably they would be better off to shift their interests to some new developments, which would have to take the place of petroleum.

Inspired by the Committee of Eleven's estimate of 108 billion barrels of shale oil, it requires little effort of the imagination to conceive that the United States originally possessed reserves totaling upwards of 40 billion barrels of recoverable oil and that in the world were 700 billion barrels of recoverable oil. There is no valid reason to think that the United States has been endowed with a share of the world's petroleum reserves in excess of a proportion equal to her proportion of the world's land area. If, as Arnold estimates, our country originally had about 42 billion barrels of recoverable oil, it might be expected that the rest of the world originally had 660 billion barrels. If 42 billion barrels of recoverable oil reserves of the United States resided in sands only 20 ft. thick; if the sands had a porosity of 25 per cent; if only 22.5 per cent of the oil was recoverable, then these 40-odd billion barrels would be overlain by less than 5 million acres of surface land and 700 billion barrels of recoverable oil in the world would be tucked away under 125,000 square miles of surface, or 0.25 per cent of the world's land area. If these possibilities are realized it will require a very high tariff to protect the owner of the last reserves in the United States from the competition of producers of much cheaper foreign oil.

If the existing restrictive measures were conceived as permanent measures whereby the time required to extract 90-odd per cent of the oil tapped by any well would be increased by 20 or 30 years, it might be

said unequivocally that the measures were uneconomic. Indeed, the prolongation of the time for return of investment from 10 or 12 years to 25 or 30 years, as indicated by present rates of recovery, disregards those fundamental trends of costs of production over which the industry exercises control. The chief social cost of oil production includes the cost of discovery, the so-called tangible and intangible development costs and the lifting and administration costs. The splendid technologic developments effected by production engineers have caused these costs to decline steadily. It is as reasonable to assume that they will continue to decline as to make any other assumption regarding the future.

Probably a continuance of the present restrictive measures will require the industry to double or even treble its investment in crude production per barrel of recovered oil. The industry will need to have as much invested in production as it now has in all branches of the industry without allowing for any additional volume. The restrictive measures provide that it shall require upwards of 30 years to recover production capital, which heretofore has been recovered in a little over 10 years, regardless of the fact that the trend of technologic improvement indicates that future developments should be made at real costs much below present costs. It is guesswork to say how much costs will be reduced by technologic improvement and it is also guesswork to say how much higher recovery can be obtained under restrictions that lengthen by two and one-half or more times the period of the recovery of reserves. On the other hand, it is an actuarial certainty that if monetary factors maintain a long-time average of values a sum of money due in the future is worth more in the present. At 6 per cent the present value of a dollar, recoverable 20 years hence, is $3.20.

Speculative considerations constitute an important aspect of the arbitrary restriction of production.

DISCUSSION

(*Clarel B. Mapes, presiding*)

Mr. Mapes* in introducing the paper stated that during the period when many people are engaged in paradoxical thinking on economic problems, it is well to consider the questioning viewpoint of the author's thesis, which cautions a careful scrutiny of actual benefits that may result from any restrictive scheme. The subject was selected with no thought of iconoclasm but rather to present analyses made with a critical eye pertaining to the arbitrary restraint of production.

For the purpose of stimulating discussion, George Otis Smith asked the author if there would have been any change in his presentation if the word "arbitrary" had been omitted from the title. Replying, Mr. Gill stated that there would have been a quite different statement regarding the apparent need for cooperation between operators. Mr. Gill said that, although a believer in conservation, he could not deplore the apparent waste of gas that had occurred in earlier years when no one knew

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the extent of reserves, and the alternative of gas wastage seemed to be that of leaving oil in the ground. However, in the light of present knowledge regarding oil and gas, a certain amount of lost individual freedom must be accepted if the greatest over-all advance is to be made.

Dr. Smith could not agree with the author in his statement that the economic production of petroleum "seems to require an unnatural relationship." Excessive above-ground inventories of oil require reduction. To bring about this reduction, some form of restriction is necessary, and to Dr. Smith the relationships of cooperative development of a common pool are natural; whether they are based upon joint or sole ownership of an oil-producing structure. The influence of demand upon a rational program designed to balance inventories is not as great as the involved, and at times contrary, human elements.

Tanker Rates and Canal Tolls as Factors Determining Markets of Foreign Oils

By Valentin R. Garfias,* New York, N. Y.

(New York Meeting, February, 1934)

With the exception of the United States and Russia, none of the leading world powers have within their boundaries the oil supplies needed to meet present peace-time requirements, and even in regard to the United States it is admitted by competent observers that the known oil reserves within the country are inadequate to meet demands for more than a comparatively few years. It follows, therefore, that the transportation of petroleum—almost entirely by tank steamers—from foreign fields to the main consuming centers is one of the most important factors affecting the present and future development of the oil industry.

The world-wide distribution of petroleum is affected by numerous factors of which international politics is not the least important. The assurance of an ample supply of petroleum—one of the most essential munitions of war—is of paramount importance particularly to those countries subjected to the rivalries of powerful neighbors. And paralleling the importance of the control of an ample supply is that of its safe transportation from the fields to the consuming centers. To illustrate: France is dependent almost entirely on foreign sources for its petroleum requirements estimated at close to 100,000 bbl. daily, and in order to control such a supply after the World War it acquired an interest in the Iraq oil fields. Lately it has undertaken the construction of a pipe line from these fields to the Mediterranean seaboard in Syria with the expectation that late in 1934 these fields will supply between 30 and 40 per cent of the country's requirements. It should be noted, however, that the availability of this supply is entirely dependent on the safe operation in the Mediterranean at all times of an adequate fleet of tank steamers. Thus, in order to transport 40,000 bbl. daily, it will be necessary for one 10,000-ton tanker to leave Tripoli, the Syrian port, say for Marseille, every other day throughout the year while to meet the entire present peace requirements of France from the Iraq fields, a fleet of some 30 such tankers must be kept in continuous operation between Tripoli and Marseille.

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* Foreign Oil Department, Henry L. Doherty & Co.

Exporting and Importing Centers

In listing the exporting and importing centers that go to make Table 1, the most important oil ports in the leading petroleum-producing and consuming countries were selected. Owing to the meager information available regarding the oil fields in the East Indies it was decided to list the refining and shipping centers of Balik-Papan, Lutung and Palembang even if any one of the three would have given substantially the desired information. Russia, the second ranking country as consumer of petroleum, was not listed as importer because it does not utilize foreign oil products. It may also be pointed out that some of the exporting centers are not located within the oil-producing countries. Curaçao, for instance, through which the bulk of the Venezuelan oil is exported, is not in Venezuelan territory, nor are Haifa or Tripoli—the English and French terminals of the pipe lines connecting the Iraq fields to Mediterranean seaboard—in Iraq.

Table 1 illustrates the general misconception existing in the public mind regarding the relative geographical location and therefore the distance between given points on the earth's surface. This is largely due to the distorted picture resulting from projecting on the flat surface of maps the terrestrial distances and areas. It may therefore be surprising to some to ascertain through this table that the harbors in northwestern Europe, such as London, Hamburg and Stockholm, are practically equidistant from New York, Constanza and the new oil harbors of Haifa and Tripoli, and that as regards the cost of marine transportation—which if it does not involve canal tolls, and everything else is equal, varies in direct ratio with the distance between terminal harbors—it is of equal advantage for the consumer, say in London, to buy oil from the American or Rumanian fields or from those in Iraq once they are connected to the Mediterranean by pipe lines. It may also be noted that the Mediterranean markets of Italy, France and Spain are not nearer to Haifa or Tripoli than to Constanza, that the fields of Colombia and Venezuela are if anything nearer to New York than are those of the Texas Gulf Coast and that the New York oil market is not nearer to California than to the Rumanian oil fields. These examples presented at random are given as suggestions for a closer study of Table 1, which shows the distances in nautical miles between the most important exporting and importing oil centers.

Tank Steamers

There are now in operation close to 1680 tank steamers, more than half of which will load on an average considerably less than 50,000 bbl. The tank steamers commonly employed in the international oil trade, on the other hand, have carrying capacities in excess of 70,000 bbl. The

TABLE 1.—*Distances in Nautical Miles between Principal Oil-exporting and Importing Centers*

	United States			Russia Batum	Venezuela Curaçao	Persia Abadam	East Indies			Mexico Tampico	Colombia Cartagena	Peru Talara	Iraq Haifa or Tripoli
	New York	Texas Ports	San Francisco				Balik Papan	Lutung	Palem-bang				
1. Antwerp	3,414	5,057	8,096 P	3,751	4,150	6,611 S	9,395 S	8,975 S	8,615 S	5,119	4,508	5,663 P	3,394
2. Barcelona	3,721	5,265	8,136 P	2,085	4,194	4,925 S	7,709 S	7,289 S	6,929 S	5,361	4,536	5,699 P	1,783
3. Buenos Aires	5,871	6,504	8,738 P	7,735	4,752	9,028	9,779	9,833	9,328	6,518	5,150	4,590	7,378
4. Cape Town	6,786	7,519	9,890	6,782 S	5,770	5,240	6,000	6,054	5,549	7,464	6,165	7,320 P	5,549 S
5. Copenhagen	3,846 K	5,499 K	8,528 PK	4,188 K	4,620 K	7,048 SK	9,835 SK	9,415 SK	9,055 SK	5,542 K	4,940 K	6,095 K	3,831 K
6. Durban	7,599	8,319	10,500	6,023 S	6,520	4,361	5,300	5,337	4,837	8,264	6,965	8,120 P	4,753 S
7. Genoa	4,062	5,606	8,477 P	1,899	4,535	4,815 S	7,544	7,124	6,764	5,709	4,877	6,040 P	1,529
8. Hamburg	3,676	5,329	8,358 P	4,018	4,450	6,878 S	9,665 S	9,245 S	8,885 S	5,372	4,770	5,925 P	3,661
9. Havre	3,220	4,478	7,898 P	3,575	3,970	6,402 S	9,189 S	8,769 S	8,409 S	5,050	4,314	5,469 P	3,186
10. Hong Kong	11,607 S	11,210 P	6,043	7,863 S	9,937 P	5,322	1,700	915	1,250	10,665 P	9,519 P	9,500	6,593 S
11. Honolulu	6,702 P	6,221 P	2,091	11,428	5,427 P	9,739	5,200	5,300	6,200	6,213 P	5,009 P	4,806	11,089 P
12. London	3,369	5,022	8,051 P	3,676	4,120	6,541 S	9,385 S	8,965 S	8,605 S	5,154	4,463	5,618 P	3,324
13. Marseille	3,897	5,141	8,312 P	2,001	4,370	4,849 S	7,633 S	7,213 S	6,853 S	5,540	4,712	5,875 P	1,707
14. Montreal	1,580	3,159	6,459 P	5,564	2,700	8,439 S	11,211 S	10,791 S	10,431 S	3,301	2,550	4,015 P	5,207
15. Naples	4,184	5,728	8,596 P	1,600	4,670	4,445 S	7,229 S	6,809 S	6,449 S	5,824	4,999	6,163 P	1,194
16. New York		1,898	5,262 P	5,603	1,769	8,450 S	11,228 S	10,808 S	10,448 S	2,030	1,853	2,829 P	5,578
17. Rio de Janeiro	4,770	5,366	7,637 P	6,580	3,650	8,521 S	9,308	9,362	8,857	5,417	4,048	5,204 P	6,223
18. Rotterdam	3,415	5,068	8,080 P	3,758	4,166	6,608 S	9,395 S	8,975 S	8,615 S	5,117	4,492	5,647 P	3,401
19. Shanghai	10,573 P	10,168 P	5,387	8,672 S	9,298 P	6,046	1,800	1,650	2,210	10,028 P	8,880 P	9,467	7,408 S
20. Stockholm	4,176 K	5,829 K	8,858 PK	4,518 K	4,950 K	7,378 SK	10,165 SK	9,745 SK	9,385 SK	5,872 K	5,270 K	6,425 KP	4,161 K
21. Sydney	9,691 P	9,330 P	6,744	9,693 S	8,416 P	7,364	4,306	4,600	4,006	9,209 P	7,998 P	6,750	8,485 S
22. Valparaiso	4,633 P	4,152 P	5,140	9,389 P	3,358 P	10,122	10,107	10,161	9,656	4,144 P	2,940 P	1,804	9,036 P
23. Vancouver	6,049 P	5,568 P	812	10,805 P	4,774 P	10,812	6,487	6,433	7,000	5,115 P	4,356 P	4,742	10,448 P
24. Wellington	8,522 P	8,370 P	5,905	10,614 S	7,247 P	8,291	4,700	5,200	5,000	7,988 P	6,829 P	5,742	9,203 S
25. Yokohama	9,699 P	9,317 P	4,536	9,364 S	8,424 P	6,762	2,700	2,300	3,000	9,165 P	8,006 P	8,429	8,127 S

P, Panama Canal. K, Kiel Canal. S, Suez Canal.
Distance from Constanza, 392 miles less than from Batum.

number of such tankers, which aggregates 625, and their average individual carrying capacities are as follows:

Number of Tankers	Carrying Capacity, U.S. Barrels
200	75,000
165	85,000
80	95,000
180	Over 100,000

After careful consideration of the various factors involved, and notwithstanding the fact that outside of certain restricted routes it is about 30 per cent cheaper to operate a foreign than an American tanker, it was decided to select as the type best suited to give a uniform basis for comparing the cost of marine transportation of petroleum, a tank steamer of American registry of 10,000 dead weight tonnage having a net carrying capacity of 75,000 bbl. operated under the following conditions:

Cost of tanker per deadweight ton	$ 50.00
Interest on investment, per cent	6
Insurance rate, per cent	5.5
Maintenance, per day	$ 60.00
Stores, per day	$ 20.00
Wages, per day	$ 100.00
Provisions, per day	$ 35.00
Overhead, per day	$ 15.00
Fuel at 75¢ per barrel, per day	$ 150.00
Port charges per trip	$1500.00
Speed, knots per hour	10
Number of crew	40
Days in port per trip	6

Canals and Canal Tolls

As before stated, the cost of marine transportation varies directly with the distance between terminal harbors and it thus follows that the use of canals that shorten such distance is economical whenever the canal tolls represent a saving over the added cost of the longer route that eliminates the use of the canal.

The oldest of these sea lanes short-cuts is the sea-level Suez Canal owned and operated by a very lucrative semi-private enterprise, which to date retains some of the characteristics of a successful monopoly. Its tolls at times have forced some of the Oriental trade, including Persian oil, to be again routed "around the Cape" on its way to northwestern Europe. To an American company, which pays now in devaluated dollars, the Suez round-trip tolls of nine "gold francs" per ton would be equivalent to 20 U. S. cents per crude oil barrel, or 9 cents more than the Panama tolls. Conversely, a French company will now pay considerably less *in francs* than formerly for the Panama Canal tolls. Before the devaluation of the dollar the Suez and Panama tolls were about 12 and 11

cents per barrel of crude oil, respectively. The Kiel Canal is operated practically at cost, with the result that the tolls per round trip of a 10,000-ton tanker aggregate only about 2¼ U. S. cents per crude oil barrel. The data in Table 2 give the salient features of the canals commonly utilized in the international oil trade.

TABLE 2.—*Data on Canals Used in Oil Trade*

	Suez Canal	Kiel Canal	Panama Canal
Year opened to traffic	1869	1895	1914
Length, miles	104	53	40
Minimum draft, feet	33	29	36
Time of crossing, hours	15	8	8
Traffic, tons:			
1930	28,511,000	22,027,000	30,030,000
1931	25,332,000	20,684,000	25,083,000
1932	23,632,000	12,851,000	19,808,000
Tolls per registered ton loaded	6 gold francs	0.231 Reich marks	$1.25
Tolls per registered ton in ballast	3 gold francs	0.193 Reich marks	$0.75
Round trip tolls per barrel crude oil	$0.20	$0.025	$0.11

As there is now a marked tendency to import crude oil for refining in the consuming countries, it was thought advisable to convert into U. S. cents per barrel of crude oil the Suez, Kiel and Panama rates, which actually are collected on gold francs, Reich marks and dollars per ton, respectively. It should be kept in mind in this connection that, owing to the difference in weight per barrel, the same tanker is able to transport, say, more barrels of gasoline than of crude oil.

COST OF MARINE TRANSPORTATION

It is interesting to note that the only pay cargo of a tanker is petroleum and its products transported generally "one way" from producer or refiner to consumer. Furthermore, tank steamers can be used economically only when transporting certain types of oil for a considerable time. Thus a "dirty tanker" on the heavy crude-oil run from Tampico to New York will require the expenditure of close to $25,000 before it can be utilized as a "clean tanker" in the transportation, say, of gasoline.

Table 3 gives the number of days required by the typical tanker to complete a hypothetical round trip which is the shortest between the ports in question. The figures imply—what is not always true—that the boat uses the same route on the return trip and that all such routes are actually followed by tanker fleets. Whenever canal transportation is utilized, it is so shown in the table. In each case the number of days given include six days "in port" per round trip, in which the cargo is loaded and unloaded and minor repairs are attended to.

TABLE 3.—*Days Required for Round Trip*

	United States			Russia Batum	Venezuela Curaçao	Persia Abadam	East Indies			Mexico Tampico	Colombia Cartagena	Peru Talara	Iraq Haifa or Tripoli
	New York	Texas Ports	San Francisco				Balik Papan	Lutung	Palem-bang				
1. Antwerp	34.8	48.1	73.9 P	37.3	40.5	61.5 S	84.7 S	81.2 S	78.1 S	48.7	43.5	53.4 P	34.3
2. Barcelona	37	49.9	74.2 P	23.3	40.9	47.5 S	70.6 S	67.1 S	64.1 S	50.7	43.8	53.8 P	20.8
3. Buenos Aires	54.9	60.2	81 P	70.5	45.5	81.3	87.5	87.9	83.7	60.3	48.9	44.2	67.5
4. Cape Town	62.5	68.7	88.4	62.9 S	54.1	49.7	56	56.5	52.2	68.2	57.3	67.3 P	52.6 S
5. Copenhagen	38.9 K	51.8 K	77.7 PK	41.2 K	44.9 K	65.4 SK	88.6 SK	85.1 SK	82.1 SK	52.6 K	47.6 K	57.2 K	38.1 K
6. Durban	69.3	75.3	93.5	56.5 S	60.2	42.3	50.1	50.5	46.2	74.9	64	74 P	46 S
7. Genoa	39.9	52.7	76.9 P	21.8	43.9	46.5 S	68.8	65.3	62.3	53.5	46.6	56.7 P	18.7
8. Hamburg	36.6	50.4	76 P	39.5	43.1	63.7 S	87 S	83.4 S	80.5 S	50.8	45.7	55.8 P	36.5
9. Havre	32.8	43.3	72.1 P	35.7	39.1	59.7 S	83 S	79.5 S	76.5 S	48.1	41.9	52 P	32.6
10. Hong Kong	103 P	99.5 P	56.3	71.9 S	89.1 P	50.3	20	13.6	16.4	95.1 P	85.7 P	85.1	61.4 S
11. Honolulu	62.2 P	57.9 P	23.4	101.2	51.4 P	87.1	49.3	50.1	57.7	58.1 P	48 P	46	98.7 P
12. London	34	47.9	73.4 P	36.6	40.3	60.9 S	84.7 S	81 S	78.1 S	48.9	43.1	53.1 P	33.7
13. Marseille	38.5	48.9	75.6 P	22.7	42.4	46.9 S	70 S	66.5 S	63.5 S	52.1	45.2	55.3 P	20.2
14. Montreal	19.1	32.3	60.1 P	52.3	28.5	76.7 S	99.9 S	96.4 S	93.4 S	33.5	27.2	39.8 P	49.3
15. Naples	40.9	53.7	78 P	19.3	44.9	43.4 S	66.7 S	63.1 S	60.1 S	54.5	47.6	57.7 P	15.9
16. New York		21.8	50.1 P	52.7	20.7	76.8 S	100 S	96.5 S	93.5 S	22.9	21.4	30 P	52.5
17. Rio de Janeiro	46	50.7	70 P	60.8	36.4	77.4 S	83.5	84	79.8	51.1	39.7	49.7 P	57.8
18. Rotterdam	34.5	48.3	73.6 P	37.3	40.7	61.4 S	84.7 S	81.3 S	78.2 S	48.7	43.4	53.4 P	34.3
19. Shanghai	94.4 P	91.2 P	50.9	78.7 S	83.8 P	56.3	21	19.7	24.4	89.9 P	80.2 P	84.9	68 S
20. Stockholm	41 K	54.5 K	80.4 PK	43.9 K	47.7 K	68.1 SK	91.3 SK	87.9 SK	84.9 SK	55.3 K	50.3 K	60.1 KP	41 K
21. Sydney	87.1 P	83.9 P	62.2	87.2 S	76.5 P	67.3	41.9	44.3	39.3	83 P	73 P	62.2	77 S
22. Valparaiso	44.8 P	40.9 P	48.8	84.6 P	34.3 P	90.3	90.2	90.7	86.5	40.8 P	30.8 P	21	81.7 P
23. Vancouver	56.6 P	52.6 P	12.7	96.3 P	46.1 P	96.1	60	59.6	64.3	49 P	42.6 P	45.5	93.4 P
24. Wellington	77.2 P	76 P	55.2	94.9 S	66.6 P	75.1	45.1	49.3	47.6	73 P	63.1 P	53.8	83 S
25. Yokohama	87.2 P	84 P	43.8	84.4 S	76.5 P	62.3	28.5	25.1	31	82.7 P	73 P	76.2	74.1 S

P, Panama Canal. K, Kiel Canal. S, Suez Canal. Days required for round trip from Constanza, 3.25 less than from Batum.

TABLE 4.—*Cost of Transporting Crude Oil in Tank Steamers*

(U. S. Cents per Barrel)

	United States			Russia Batum	Venezuela Curaçao	Persia Abadam	East Indies			Mexico Tampico	Colombia Cartagena	Peru Talara	Iraq Haifa or Tripoli
	New York	Texas Ports	San Francisco				Balik Papan	Lutung	Palembang				
1. Antwerp	36	41	73 P	32	35	72 S	91 S	88 S	85 S	41	38	57 P	30
2. Barcelona	32	43	74 P	21	35	60 S	80 S	77 S	74 S	43	38	57 P	19
3. Buenos Aires	47	51	79 P	60	39	69	74	74	70	51	42	38	57
4. Cape Town	53	58	74	74 S	46	42	47	47	45	58	48	68 P	65 S
5. Copenhagen	36 K	46 K	78 PK	37 K	40 K	77 SK	95 SK	93 SK	91 SK	47 K	43 K	50 K	35 K
6. Durban	58	64	78	68 S	51	36	43	43	40	63	54	73 P	60 S
7. Genoa	35	45	76 P	20	38	60 S	58	55	53	46	40	59 P	18
8. Hamburg	32	43	75 P	34	37	74 S	93 S	90 S	88 S	43	40	59 P	32
9. Havre	29	37	72 P	31	34	70 S	90 S	87 S	84 S	41	36	55 P	28
10. Hong Kong	97 P	94 P	48	81 S	86 P	43	74	13	15	91 P	83 P	72	72 S
11. Honolulu	64 P	60 P	21	85	55 P	72	48	43	49	61 P	52 P	40	94 P
12. London	30	41	73 P	32	35	71 S	91 S	88 S	86 S	42	37	56 P	29
13. Marseille	33	42	75 P	21	37	60 S	79 S	76 S	74 S	44	39	58 P	18
14. Montreal	18	28	62 P	45	25	84 S	103 S	100 S	98 S	30	24	46 P	42
15. Naples	35	46	77 P	19	38	57 S	77 S	73 S	71 S	47	41	61 P	15
16. New York		20	54 P	45	19	84 S	103 S	101 S	98 S	21	19	38 P	45
17. Rio de Janeiro	40	43	70 P	52	31	85 S	70	70	67	43	35	54 P	49
18. Rotterdam	30	41	73 P	32	35	72 S	91 S	88 S	85 S	42	37	56 P	30
19. Shanghai	90 P	87 P	44	86 S	81 P	48	20	18	21	86 P	78 P	71	77 S
20. Stockholm	37 K	49 K	80 PK	40 K	43 K	79 SK	98 SK	96 SK	93 SK	49 K	44 K	64 KP	37 K
21. Sydney	84 P	81 P	53	93 S	75 P	57	36	38	33	81 P	73 P	52	85 S
22. Valparaiso	49 P	46 P	42	82 P	42 P	75	75	76	73	46 P	39 P	19	80 P
23. Vancouver	59 P	56 P	12	92 P	51 P	80	51	51	54	53 P	48 P	39	89 P
24. Wellington	75 P	74 P	47	100 S	67 P	64	39	42	41	73 P	64 P	46	90 S
25. Yokohama	84 P	82 P	38	90 S	76 P	53	25	23	27	81 P	72 P	64	82 S

P, Panama Canal. K, Kiel Canal. S, Suez Canal. Constanza rates about 1½ cents lower than Batum.

Table 4 shows the cost per round trip of transporting crude oil in the typical American tanker—it should again be noted that foreign boats operate about 30 per cent cheaper than those under American registry—between the most important exporting and importing centers; it is based on the cost of operating said tanker during the days as shown in Table 3 required for the shortest round trip; canal tolls, if any, are included in Table 4, which gives the cost on the basis of U. S. cents per barrel. The figures in this table are of necessity but approximately accurate. In actual practice obviously many of the routes shown are seldom if ever followed; also, it should be possible, for instance, to charter a tanker at a lower rate for a number of trips than for only one. Again, the newer and larger tankers, which carry as much as 163,000 bbl., naturally operate more economically on certain routes than the type of tanker selected here. Also, an oversupply of tankers, an undersupply of oil or a low consumption in a particular region of all or any one product may limit or reduce exports and compel the rerouting of oil shipments. Thus the fields in the East Indies are limited in their production of kerosene, which finds a ready market in the Orient, by their inability to dispose of the gasoline that is obtained in manufacturing the marketable product. This and many other similar considerations notwithstanding, it is believed that Table 4 shows, not the actual charter rates throughout the world at any one time, but what it intends to show, i. e., the basis for a comparative study of the effect of tanker rates and canal tolls in determining the marketing range of foreign oils. It is only with these limitations in mind that the data herein contained should be interpreted. Finally, it should be kept continually in mind that the cost of operating tank steamers under foreign registry is about 30 per cent lower than under the American flag and that as a result American tankers can compete successfully with foreign boats only when plying between American harbors. In actual practice, therefore, the figures in Table 4 may reflect quite closely the cost of transportation between American harbors, San Francisco or Texas ports to New York, for instance, and, also, say, between Tampico, Cartagena or Curaçao and the American harbors in the Gulf or the Atlantic seaboard. On the other hand, the transatlantic, transpacific, European and Oriental routes are obviously controlled by the more cheaply built and operated foreign tanker.

Normal and Basic Prices of Crude Petroleum*

By Norman D. Fitz Gerald,† New York, N. Y.

(New York Meeting, February, 1934)

The mathematical analysis, which is an essential part of this paper, has revealed the interesting fact that contrary to the opinions of many, determinate and measurable economic factors are largely responsible for the price of crude oil. It should, however, be well understood that the results of this analysis are applicable, without qualification, only to the particular period and market studied.

There are certain peculiarities of the petroleum industry which make the consideration of its economics very difficult, and at times practically impossible. Noneconomic factors often become highly important and have serious economic effects, which make unqualified predictions based on economic data extremely hazardous and ill advised. However, in spite of the attendant difficulties there are many problems, especially in price analysis, to which approximate solutions must be made for the proper guidance of public and private policy, but their limitations should be kept clearly in mind.

An understanding of the nature of prices is of fundamental importance for a number of purposes. Measurement of the motivating factors giving rise to trends and other price movements is essential to forecasting for the intelligent engineering and financial administration of the industry. The fixing of prices, maintenance of an intelligent industrial dictatorship, or the making of other industrial adjustments, demand, for success, an accurate understanding of their probable consequences. The establishment of a system of equitable relations within an industry, or between industries, by methods other than the natural competitive ones, requires a thorough knowledge of the price structures and the nature and trends of the normal and basic prices of their products. This research has shown that in this case, even though the statistical records are only fair, quantitative economics offers a direct and satisfactory approach to the problems of economic consequences dependent on the reactions of mass intelligence.

A consideration of commodity prices naturally leads to costs. The true cost of petroleum is so complex and elusive that its accurate deter-

* The research work for this paper represents a portion of a thesis presented in partial fulfillment of the requirements for the degree of Doctor of Science in Mining, from the Department of Mining and Metallurgy of the Massachusetts Institute of Technology, Cambridge, Massachusetts.

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mination is impossible. No definite relations exist between the cost of prospecting and the value of the petroleum discovered, or the cost of a well and the value of its production. Each barrel is actually produced at a different cost. The problem becomes even more complex when byproducts, changes in technology, differences in crude oils, and unknown depletion rates are considered. It is, however, possible to make approximations to the cost of petroleum.

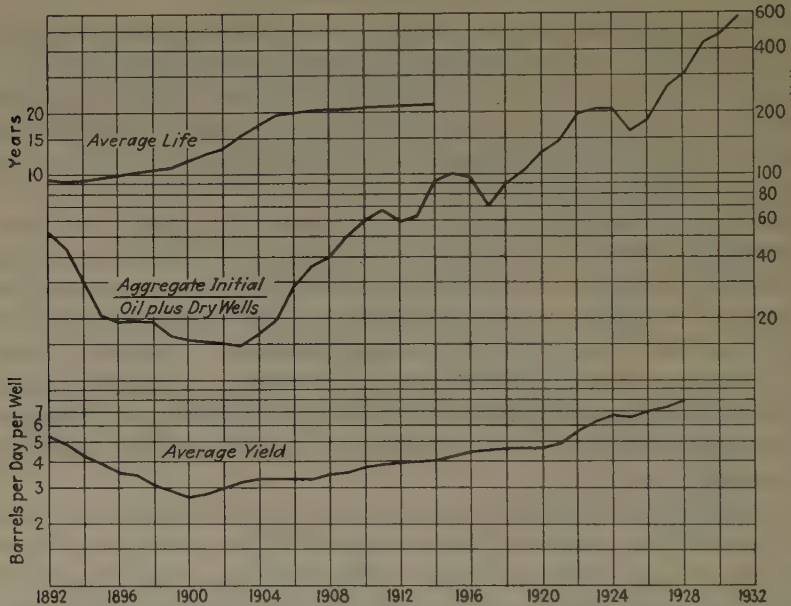

FIG. 1.—TRENDS OF INITIAL, YIELD AND LIFE OF PETROLEUM WELLS IN THE UNITED STATES, 1892 TO 1932.

The trends of both price and cost of petroleum have been predominantly downward over the past 40 years, although not necessarily at the same rate. As indicated in Fig. 1, the initial production per well drilled for oil has increased some 20 times while the rate of production and the life of the average producer have been increasing. These factors offset, at least in part, the increase of about 10 times in the cost of wells and the higher lifting costs natural with greater depths. During the four decades over 14,380,000,000 bbl. of petroleum have been produced in the United States. The rapid and almost continuous growth in petroleum production is sufficient indication that the profits, over a period, are satisfactory to the producing division of the industry; for in general there tends to be a rough equality of profits in all industries. The fact that the petroleum industry may obtain a part of its profit in the form of speculative appeal, rather than cash, does not affect the logic of this analysis.

The price of crude petroleum has been analyzed by mathematical analysis. There is, however, no rigid mathematical foundation to the

science of economics. Its laws are human reactions predicated on the assumption that the masses will react in a predetermined and generally fixed manner to all situations of like character. The economist applying mathematical methods finds the state of dynamic equilibrium the simplest case with which he has to deal, and even this is complicated by the fact that human beings do not act on the basis of facts and reality, but upon knowledge that is a synthesis of opinions and beliefs about facts. Furthermore, economic effects can, in some degree, be modified by external control and therefore subjected to distortion, varying them from true mathematical laws. All that the economist can hope to do is to describe what is observed to happen, reveal the hidden uniformities behind apparently random, capricious happenings, and formulate the tendencies of mass action and intelligence in economic affairs in terms as general as possible. The changing complexities of man and his world, however, make practical and general solutions of the problems of industrial economics difficult in the extreme if not impossible.

Normal Price

The law of supply and demand is not as rigid as the laws of physics, and there is always a range of uncertainty about the equilibrium price. Within this shadowland of variation in the short-term price, human nature and a host of other indeterminate factors tend to cause fluctuations quite unrelated to supply and demand in the abstract sense. In statistical analyses the difficulties in deducing the law of supply and demand are complicated by inaccuracies and incompleteness in the available data. There is, however, a long-term balancing of supply and demand, an averaging of the price uncertainties, giving rise to the concept of a natural or normal price.

The nature of the normal price was well known to Adam Smith, the great economist of the eighteenth century; he wrote the following:

> The natural price, therefore, is, as it were, the central price, to which the prices of all commodities are constantly gravitating. Differing accidents may sometimes keep them suspended a good deal above it, and sometimes force them down even somewhat below it. But whatever may be the obstacles which hinder them from settling in this center of repose and continuance, they are constantly tending towards it.
>
> But though the market price of every particular commodity is in this manner constantly gravitating, if one may say so, towards the natural price, yet sometimes particular accidents, sometimes natural causes, and sometimes particular regulations of police, may, in many commodities, keep up the market price for a long time together a good deal above the natural price.
>
> The natural price itself varies with the natural rate of each of its component parts, of wages, profit, and rent; and in every society this rate varies according to their circumstances, according to their riches or poverty, their advancing, stationary, or declining condition.

Herbert Hoover, in his "Principles of Mining," developed the normal prices of metals, not from strict averages, but by considering the general outlook combined with the previous records.

The normal price is the trend value of the dynamic equilibrium of normal supply and normal demand, all other factors changing at their normal rates. Adam Smith and Herbert Hoover both recognized the fact that the normal price is not an average price except in the static state, for there are secular movements of normal prices related to changes in industries, competition, capital, population, habits, and knowledge as reflected in the evolving conditions of supply and demand from one generation to another.

The normal price is not a simple average price, but is a complex and continuously changing price, which would prevail if perfect dynamic equilibrium existed between normal supply and normal demand, while other factors changed normally. If the market price is displaced from it, corrective influences are exerted to return the price to its central position. This normal price may be represented by a mathematical function and possesses the properties of a mean price, about which the market price fluctuates.

The normal price of petroleum is obscured by the enormous variance in the productivity of oil pools and the random characteristics of their discovery in time. There are some wildcatters who are not so concerned about the price of oil as are others, therefore prospect drilling is not always based on economic wisdom. Occasionally it is the part of individual wisdom to drill in generally poor circumstances to fulfill contracts or confirm or deny the value of properties held under lease. These peculiarities of prospect drilling, coupled with the legal interpretation of the usual oil lease, the migratory character of petroleum, the nature of its cost, and the attractiveness of cheap flush production, exert a most disconcerting effect on the price structure from time to time. A series of coincidences in successful prospecting, not prompted by sound economic judgment, might keep the price of petroleum below normal for as long as a decade. The normal price is, then, a theoretical price, and its quotation is quite accidental and transitory.

The nature of the normal price varies with the phase of industrial growth. During the early development years of an industry the normal price is indeterminate. When a trend of production emerges and rapid growth occurs it is evident that profits, or anticipated profits, are large. The market price for a product in a rapidly growing industry is close to or above the normal price. If this were not so new capital would not be attracted to expand the industry and so continue its growth. The maturity of an industry is generally accompanied by a reduction in profits, therefore it is reasonable to expect the relation between cost and price to become more evident as the rate of industrial growth declines. In a stable

or declining industry the price is below normal more of the time, else the industry would grow because of its profit potentialities. If liquidation is taking place in a declining industry the market price may be below normal continuously. This is possible because operating enterprises cannot stand heavy losses for long, and bankruptcies and reorganizations permit the gaining of a normal profit when the market price for the product is below normal. This is especially true when capital costs are relatively high, and depreciation, depletion and obsolescence are low. The concept of normal price is clearest in a stable or growing industry, for the normal is often indeterminate in a new or declining industry because there is a tendency for prices to fluctuate widely and normal trends are difficult to discern.

Short-term normal prices may occasionally, be quite different, from those of preceding or succeeding years. In case of a war, when normal costs and normal profits for the temporary and peculiar conditions are high, the price required to maintain the normal supply may be high. This type of short-term change in normal is particularly evident in the case of petroleum.

The normal price approaches the trend price if a period of sufficient length is taken. The long-term balancing of the factors of supply, demand, cost, profit, and so forth, permits a close approximation to the true normal price. Data for the period 1892 to 1932, inclusive, have been used in this study. During these years there have been 14,380,000,000 bbl. of petroleum produced in the United States, 2,390,000,000 bbl. exported, and 1,479,000,000 bbl. imported under the influence of an annual average price which has varied from 51¢ to 307¢, and has averaged 110.

The war period complicates the determination of the normal price. Prices rose sharply during the war and the perturbations of war in the economic system will reverberate for many years. It is not possible, nor would it be desirable, to eliminate the effects of the war from consideration. The long-term trend of oil prices is downward, in part owing to decreasing grade, therefore special care had to be taken in the selection of a type of trend that would follow prices during the war but minimize its effects on the remainder of the period.

The trend of oil prices is difficult to formulate. During the pre-war period the price fluctuated widely but with a general downward tendency; the price rose from 64¢ in 1915 to 307¢ in 1920; from 1920 the price declined most of the time, except for the sharp rise of 1925 and 1926, with a characteristic wide variation. Straight lines, trending downward, appear to offer the most logical description of the prices during the pre-war and post-war years. For the war period rapidly changing functions, which later became asymptotic, are required to follow the rapid rise and subsequent fall of prices to a level different from that of pre-war

times. The common function that satisfies the conditions is the inverse, or arc, tangent. In Fig. 2 the normal price is shown defined by an equation in which 1917 is the origin, 1.5 is the x unit, and the price of petroleum is in cents per barrel of 42 U. S. gal.; and the coefficients of which have been computed by the method of least squares.

During the period studied there has been a downward tendency of about 1.58¢ per barrel per year in the normal price, an indeterminate portion of which is due to the decreasing grade of oil and the increasing value of byproducts. The decline in the normal price is especially interesting, for it is in spite of increases in taxation, general commodity prices and the cost of drilling an average well.

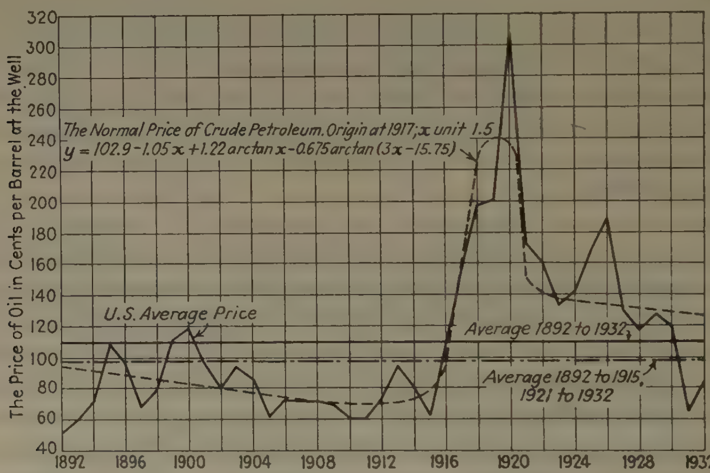

FIG. 2.—NORMAL PRICES OF CRUDE PETROLEUM IN THE UNITED STATES, 1892 TO 1932

THEORY OF THE BASIC PRICE

The concept of basic price is more difficult than that of normal, and few have attempted to define it even in theoretical terms. In general, it is a stable level below the normal price and represents the resistance established by the lower edge of the shadowland of indetermination in the normal price. The basic price possesses the properties of a minimum price above which, for the most part, the market price fluctuates. Under ordinary conditions the market price will not drop below the basic price without affecting the supply.

Adam Smith did not define the basic price, or any similar concept. It is quite possible that, since his "Inquiry into the Nature and Causes of the Wealth of Nations" was written at the beginning of the industrial revolution, its author overlooked the basic price; for in agriculture its application is even more subtle than in the manufacturing and mining industries in which high overhead costs and hired labor have accentuated the importance of the basic price.

Alfred Marshall, the famous economist of the nineteenth century, defined the basic price in a general way when he wrote of a controlling influence over the relatively quick movements of prices during short periods which is exercised by causes in the background ranging over a long period, and the fact that the fear of spoiling the market often makes these causes operate more quickly than otherwise they would.

Herbert Hoover, in conjunction with his consideration of normal prices, developed the concept of basic price in a more practical manner and wrote:

> There is at this point what we may call the "basic" price, that at which production is insufficient and the price rises again . . . the writer has not followed strict averages, but has taken the general outlook combined with the previous records. . . .

The basic price is a most complex and hidden characteristic. The obvious, although often false, approach to its determination is through a study of low prices. The basic price, however, is not necessarily the lowest price reached, although it is often considered as a kind of normal of depressed times, which might be developed through a study of turning points. Unfortunately this simple type of analysis is quite inadequate, for turning points are not homogeneous. The price level, business activity, relation of stocks to consumption, relative success of prospecting, and many other factors vary in a more or less random fashion, within limits, from one turning point to another. For this reason the depth of the price below basic is a variable. The simple but improper method would imply that the basic price is necessarily related to business depressions, excess of supply over consumption, and that it possesses a discontinuous nature. Usually turning points are only indications of price stability, rather than instability, and economic price equilibria may be maintained continuously through them as simply as if the price changed slowly.

The basic price is just as truly a continuous characteristic as the normal price. The difficulties of analysis do not alter the fact that at the peak of prices there is a real, underlying, stable basic price which represents the lower edge of the shadowland of indetermination of the normal price of stable dynamic equilibrium. Marshall indicated that this price was the lower limit of prices under ordinary conditions. Hoover presented definite figures for the basic prices of metals, but wrote of the basic price of depressed times, acknowledging that there were other basic prices. Mathematical analysis to reveal the underlying economic laws, seems to be the only satisfactory method of approach to a dynamic description of the nature of petroleum prices.

The development of the basic price of petroleum requires a consideration of the major statistically determinate factors affecting the price, simultaneously, *en masse*. Since basic prices are related to the lower limit of prices under ordinary conditions, and ordinary, or normal condi-

tions, are really most extraordinary in the rarity of their occurrence, it is necessary to simulate normal conditions by correcting the abnormal for all measurable disturbing factors.

Methods of Analysis

The multiple correlation analysis is a statistical method for the simultaneous determination, by the method of least squares, of the best weights to use in combining the statistical series of independent variables to explain fluctuations in the dependent variable, in accordance with any assumed functional relationships. It has been assumed that changes in the dependent variable are related to the sums of the deviations of the independent variables; that is, the relations are additive rather than complex. This probably is true in this particular case, but is by no means true in many types of economic phenomena. The purpose of the analysis is to derive an estimating equation for approximating the price that would have obtained if the factors considered were the only influencing ones, followed the assumed laws exactly, and maintained their average relative importance unchanged through the period.

The major influences upon petroleum prices which can be expressed by statistical series are as follows:

A. The price of petroleum the previous year.
B. The price level.
C. Business activity.
D. The rate of change of available petroleum.
E. The rate of change of petroleum demand.
F. Petroleum demand.
G. Petroleum available.

The price of petroleum is the weighted average price at the wells, in the United States, as determined by the Bureau of Mines. The price level is the United States Bureau of Labor Statistics index of wholesale prices. Business activity is the index prepared by Leonard Ayres, of the Cleveland Trust Co. The rate of change of available petroleum is the link relative, the value for the present year divided by that of the last year, of series G. The rate of change of petroleum demand is the link relative of series F. Petroleum demand is production minus changes in previous year-end pipe line stocks minus exports plus imports. Available petroleum is production plus previous year-end pipe line stocks.

There is a logical reason for the inclusion of each of these factors. The price of petroleum the previous year is the resultant of the forces which displaced the price from normal, and there may be a tendency for these forces to persist, or to exert an opposite effect upon subsequent prices. The price level indicates, roughly, the changing cost of petroleum production, and the price the public can afford to pay. Business activity measures the commercial demand. The rates of change of available

petroleum and petroleum demand are early indicators of a change in short-term trend, hence may be expected to aid in the explanation of price movements. Available petroleum, and petroleum demand, are economic factors of unquestioned importance.

The unit used to compare these widely varying series in their effects upon petroleum prices is somewhat complicated. In order to study the

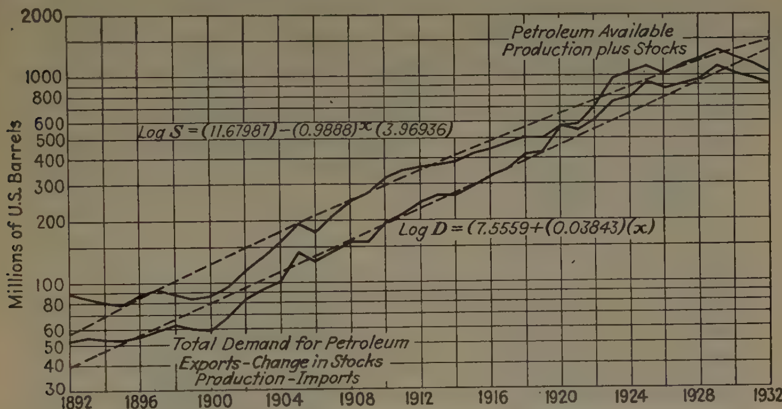

FIG. 3.—PETROLEUM AVAILABLE AND TOTAL DEMAND, UNITED STATES, 1892 TO 1932.

fluctuations in relative terms it was necessary to remove secular trends by the assumption of mathematical laws of change which were of a reasonable character; these are shown in Figs. 3 and 4. The actual figures were divided by the normal, or trend values, to obtain a percentage of normal series. A spurious trend of negligible economic significance was introduced by the division, and this was removed by the use of a straight line.

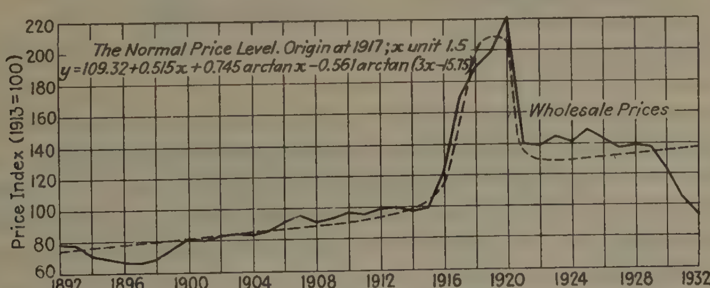

FIG. 4.—WHOLESALE PETROLEUM PRICE INDEX (1913 = 100), UNITED STATES, 1892 TO 1932.

The final series for correlation analysis was in terms of deviations from the trend of percentages of the trend of the normal.

The statistical price of petroleum estimated from the equation derived by correlation analysis, as shown in Fig. 5, conforms very well with the actual price. The computed price indicates what the price would have been had the laws assumed been perfect, had no other factors affected the

price, and had each factor maintained its average effect throughout the period.

The accuracy of an estimating equation derived by the methods of multiple curvilinear correlation is generally measured by the multiple index of correlation. The value of the index may vary from $+1$ to -1, the sign depending upon the direct or inverse character of the relationship. The estimating equation developed in this analysis has a multiple index of correlation of $+0.7215$, and a probable error of ± 0.0443. The significance of a relation is measured by the ratio of the index of correla-

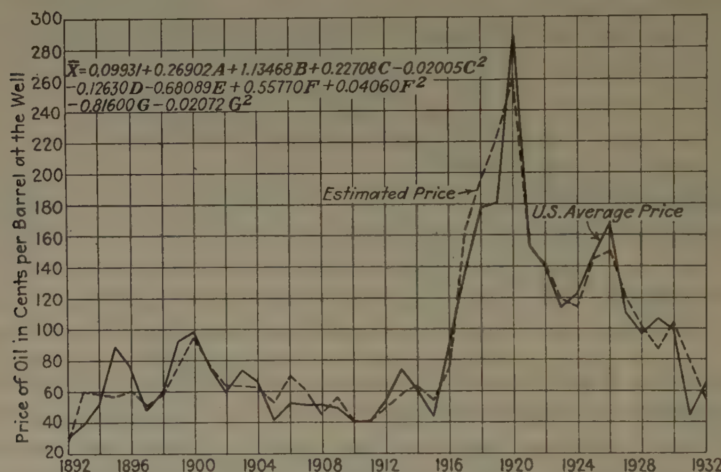

FIG. 5.—STATISTICAL PRICE OF PETROLEUM, UNITED STATES, 1892 TO 1932.

$\bar{X}$. Estimated price.	D. Rate of change of available.
A. Price previous year.	E. Rate of change of demand.
B. Wholesale price index.	F. Petroleum demand.
C. Business activity.	G. Petroleum available.

All these factors are computed in terms of deviations from the trend of the percentages of trend of the normal trends.

tion to its probable error. If this ratio is above 6, and is supported by independently logical reasoning, a fairly dependable covariation in the series has been established. In this case the ratio is 16.3. The general concurrence of the fluctuations, as indicated in Fig. 5, of the actual and the estimated price, is quite remarkable in the light of the nonstatistical disturbances.

THE BASIC PRICE

The basic price is related to economic friction and inertia, which compose that complex of unknown factors not included in the statement of economic laws. These factors reduce the correspondence between the scientific generalization and the actuality. The action of the law of price is not smooth and instantaneous. Prices do not constantly oscillate back and forth, for a considerable time may elapse before a change in

demand or supply works out its effect in price and quantity sold, while small variations may have negligible effects. Continual change, a characteristic of the economic world, prevents the establishment or continuance of equilibrium, and even the tendency towards equilibrium is not smooth, regular and constant.

The basic price has been determined from a study of the actual price, the statistical price, and the normal price. The statistically inexplicable laws were converted into percentages below the normal price, adjusted to cents per barrel, and a curve similar to that of the normal price fitted. In Fig. 6 the basic price is compared with the more rapidly declining normal price, and the actual price.

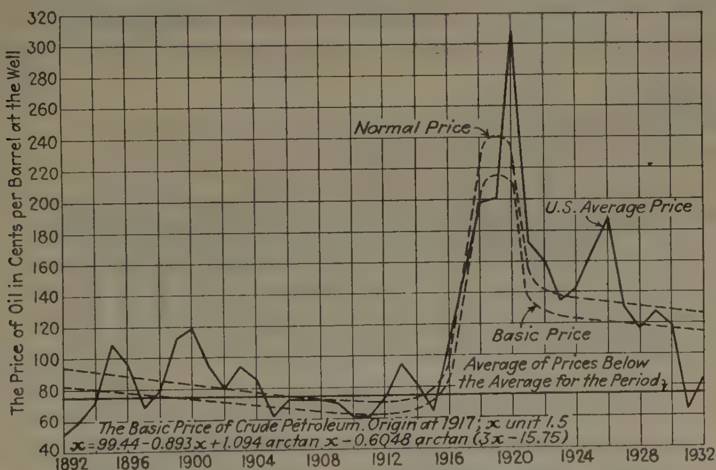

Fig. 6.—Basic prices of crude petroleum, United States, 1892 to 1932.

Summary

The normal and basic prices of petroleum are declining, the former at the rate of 1.58¢ per barrel per year and the latter at the rate of 1.34¢; if corrections are made for the upward influence of the general price level, the declines relative to it are 2.25¢ and 2.02¢, respectively.

Unless unforeseen events of major importance occur, the declining trends of normal and basic prices now in evidence will probably continue for many years in spite of the inevitable flurries due to temporary conditions. The decline of prices eventually will cease as the industry enters a period of stabilized costs. When and if technology is no longer able to compensate for the natural consequences of the depletion of shallow oil reserves near consuming centers, first the basic price and then the normal price will rise, relative consumption will be restricted by higher prices, and the industry will assume the characteristics of decline.

Seasonal Variation in Gasoline Consumption

By Joseph E. Pogue,* New York, N. Y.

(New York Meeting, February, 1934)

That the domestic consumption of gasoline displays a marked seasonal variation, with a low in the winter and a high in the summer, is well known. It is logical to expect that the nature of the variation has itself been undergoing a change as a result of improvement in roads, general employment of closed cars, and growth of mass haulage; but so far as I am aware the *change* in seasonal variation has never been investigated

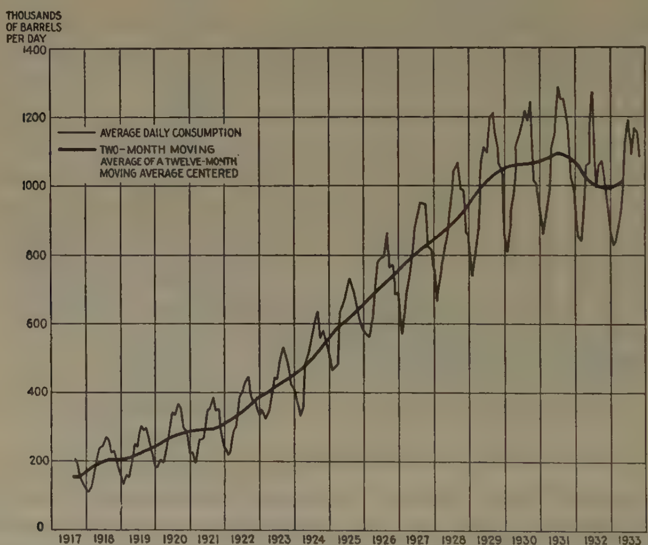

Fig. 1.—Average daily consumption of gasoline in United States, 1917–1933. Shows also the trend of the series determined by fitting a curve representing a two-month moving average of a twelve-month moving average of the original data. The deviations of the raw figures from the trend represent the seasonal tendency.

and measured. It is the purpose of this paper to present the method and results of such an investigation, undertaken as a contribution to the technique of planning operating schedules now so prominent in connection with the functioning of the industry under a Federal quota system.

For the method employed I am indebted to the suggestions and help of Frederick R. Macaulay,[1] who kindly looked over the work sheets; and

* Consulting Engineer.

[1] See also F. R. Macaulay: The Smoothing of Time Series. National Bureau of Economic Research. New York, 1931.

credit is due Barnabas Bryan, Jr., for assisting in the computations and the graphic work. Ideas for the approach to the problem were also derived from an article by Aryness Joy and Woodlief Thomas of the Division of Research and Statistics of the Federal Reserve Board.[2]

The data employed are the monthly figures for domestic gasoline consumption from August, 1917, to October, 1933, the entire period for which statistics are available by months. The sources of the data are the published reports of the U. S. Bureau of Mines, but the figures for 1931–1933, which are published on a motor-fuel basis, were recalculated to a gasoline basis according to the formula employed in computing consumption for the 1917–1930 period, so that the entire series should be homogeneous. The method employed in the investigation embraces the following steps:

1. The monthly consumption figures are reduced to a daily rate basis and plotted.

2. A smoothed curve is then fitted to this series by computing a two-month moving average of a twelve-month moving average and centering. See Fig. 1.

3. The percentage deviations of the original data from the smoothed curve are next computed and segregated by months.

4. The deviations for each month are then plotted separately; a five-year moving average fitted to each set; and the trend thus indicated is smoothed (Fig. 2). The result indicates the trend of the seasonal factor for each month.

5. Next the smoothed curve for each month is graphically converted into the corresponding percentage deviations and these figures, after minor adjustments prorated so as to make the sum of the months for each year equal to 1200, become the seasonal factors. Thus a seasonal for each year is obtained. The 1934 seasonal is derived by extrapolation of the smoothed curve of percentage deviations.

The results obtained from these successive computations may be summarized by reference to the accompanying charts. Fig. 1 shows the daily rate of domestic gasoline consumption from August, 1917, to the present, with the trend of these figures indicated by the heavy line. The fluctuations of the monthly figures (light line) about the trend (heavy line) measure the seasonal tendency.

Fig. 2 shows for each month separately the seasonal tendency (light line) with the trend, indicated by the heavy line. The trend shows clearly that the seasonal factor has been changing and measures the direction and degree of this change. It is apparent from Fig. 2 that the seasonal factors have been rising in the winter and declining in the summer; and the amplitude of the seasonal variations is narrowing.

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[2] The Use of Moving Averages in the Measurement of Seasonal Variations. *Jnl. Amer. Statistical Assn.* (1928) **23,** 241–252.

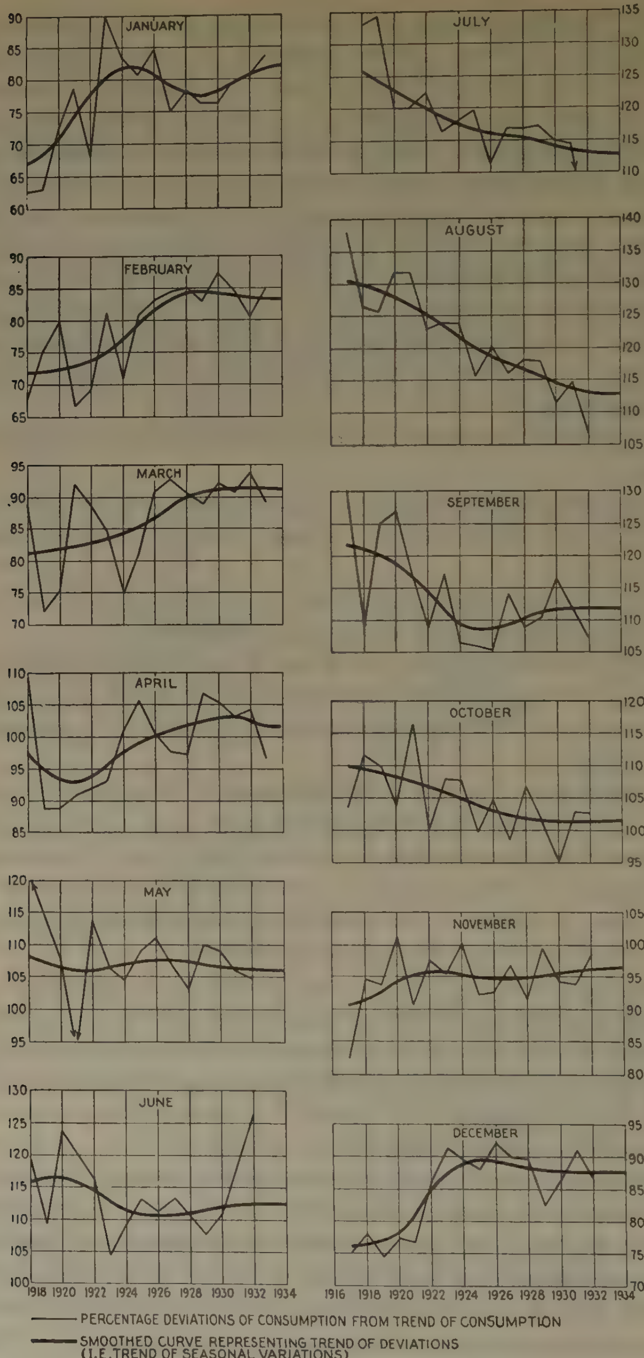

FIG. 2.—CAPTION ON OPPOSITE PAGE.

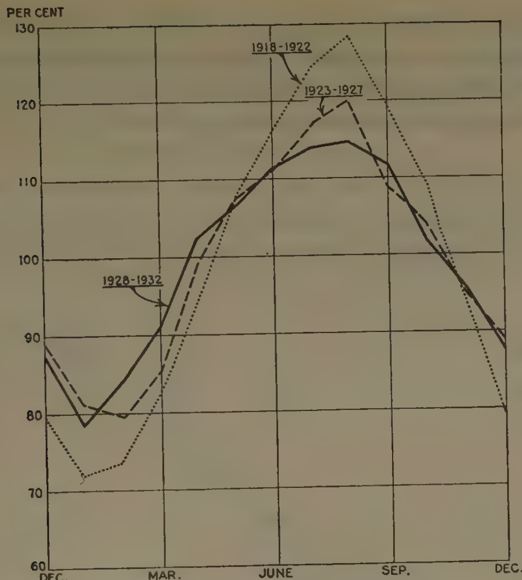

FIG. 3.—SEASONAL VARIATION OF DOMESTIC GASOLINE CONSUMPTION FOR THREE SUCCESSIVE FIVE-YEAR PERIODS.

Showing flattening of seasonal factors in summer and decreasing amplitude of seasonal variations.

TABLE 1.—*Seasonal Variation of Gasoline Consumption in the United States for Three Successive Five-year Periods and for* 1933 *and* 1934

(Expressed in Per Cent of Trend)

	1918–1922	1923–1927	1928–1932	1933	1934
January	71.7	81.3	78.5	81.6	82.0
February	73.0	79.6	84.1	84.1	84.1
March	82.8	85.5	90.9	91.1	91.1
April	94.6	99.4	102.6	101.6	101.4
May	107.4	107.7	106.7	106.6	106.5
June	116.3	111.2	111.5	111.8	111.8
July	123.9	117.1	114.1	112.7	112.5
August	128.4	120.0	114.8	112.7	112.6
September	119.1	109.3	111.7	112.0	112.0
October	108.8	104.3	101.5	101.6	101.7
November	94.7	95.3	95.8	96.6	96.7
December	79.3	89.3	87.8	87.6	87.6
Totals	1200.0	1200.0	1200.0	1200.0	1200.0

FIG. 2.—TREND OF SEASONAL VARIATION OF DOMESTIC GASOLINE CONSUMPTION FOR THE PERIOD, 1918–1933.

Determined by plotting percentage deviations from trend of original series and measuring tendency of deviations by smoothing a curve representing a five-year moving average of deviations, centered. Note that seasonal factors tend to decline in warm months and to rise in cold months.

The change in seasonal variations may be visualized from Fig. 3, which shows in three superimposed curves the seasonal factors for three successive five-year periods: 1918–22, 1923–27, 1928–32. The data on which these curves are based are given in Table 1.

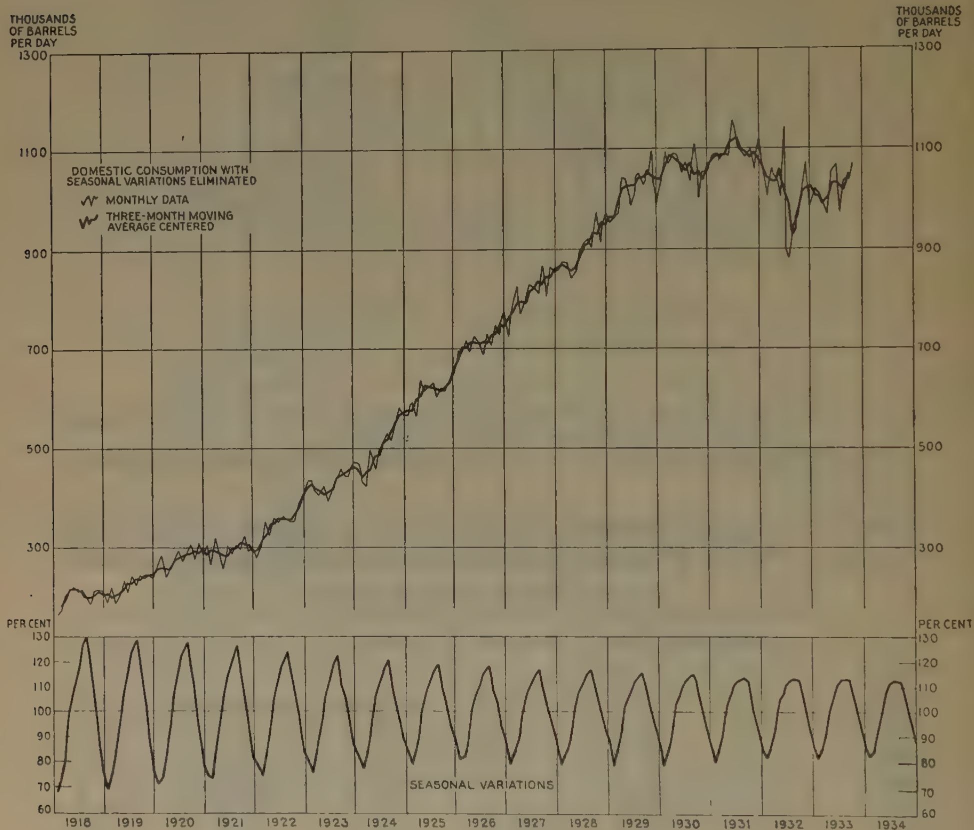

Fig. 4.—Average daily consumption of gasoline in the United States with seasonal variation eliminated, together with the seasonal variations separately shown, by months.

Note flattening tendency of seasonal curve in summer months and narrowing amplitude of entire series of seasonal variations.

Fig. 4 is designed to illustrate the trend of domestic gasoline consumption with the seasonal factors eliminated (upper curve), together with the seasonal variations separately shown (lower curve). The latter indicates the flattening tendency in the summer and the narrowing amplitude between winter and summer.

For practical purposes in forecasting and setting quotas, the seasonal factors for 1933 and 1934 are of principal interest. The figures for these years are shown in Table 1. These factors may be used for detecting the trend of current statistics as they appear and as a multiplier for converting forecasted trend into monthly estimates.

In summary, this paper demonstrates that the seasonal variations in domestic gasoline consumption are changing, measures the direction and degree of such change, and provides seasonal factors for the years 1933 and 1934.

World Petroleum Consumption

By V. R. Garfias and R. V. Whetsel,* New York, N. Y.

(Thousands of Barrels)

	1931						1932						1933					
	Gasoline	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Gasoline	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Gasoline	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
United States	405,113	45,013	378,105	27,008	45,011	900,250	373,770	33,310	307,678	16,697	102,227	833,682	378,143	38,440	321,395	17,066	110,443	865,487
Russia	5,400	19,800	56,700	2,700	5,400	90,000	6,800	22,770	54,950	4,320	7,656	96,496	8,520	23,925	49,542	6,118	4,715	92,820
United Kingdom	28,202	6,430	22,869	2,800	1,800	62,101	30,500	7,188	21,404	2,764	1,700	63,556	34,340	6,262	23,331	3,064	1,263	68,260
France	19,165	1,898	6,941	1,932	1,810	31,746	19,571	1,584	8,828	1,768	1,814	33,565	21,490	1,602	11,331	2,135	2,360	38,918
Canada	16,151	1,316	13,800	836	1,645	33,748	15,440	1,036	13,740	721	1,100	32,037	14,435	1,010	13,520	646	1,020	30,631
Germany	14,547	1,246	4,647	2,326	1,976	24,742	12,789	860	4,393	2,015	1,620	21,677	12,373	812	5,564	1,880	1,560	22,189
Argentina	5,346	1,082	13,165	329	860	20,782	4,554	832	12,244	287	820	18,737	5,410	992	13,165	392	840	20,799
India	2,220	6,296	4,440	740	1,100	14,796	2,389	6,916	3,668	770	1,236	14,979	2,303	6,610	3,990	751	1,310	14,964
Mexico	1,749	489	8,098	138	4,260	14,734	1,717	389	8,935	141	3,463	14,645	1,765	357	10,407	124	2,341	14,994
Japan	5,159	846	6,807	1,304	520	14,636	4,792	850	6,127	1,344	530	13,643	5,227	861	6,419	1,321	560	14,388
Rumania	760	1,320	9,589	197	1,570	13,436	706	1,225	9,701	190	1,520	13,342	725	1,246	10,482	146	1,583	14,182
Dutch East Indies	1,798	2,489	6,098	515	1,420	12,320	1,687	2,510	5,750	531	1,356	11,834	1,402	2,183	5,610	515	1,241	10,951
Italy	3,541	1,236	5,910	834	348	11,869	2,915	1,102	5,323	801	229	10,370	3,543	1,110	6,582	884	320	12,439
Australia	6,095	1,005	1,083	313	610	9,106	5,359	990	772	413	513	8,047	5,849	873	819	379	342	8,262
Dutch West Indies	154	20	5,621	27	2,591	8,413	156	19	5,200	22	2,486	7,883	161	21	5,490	28	2,310	8,010
Persia	423	1,280	3,300	681	1,342	7,026	461	1,200	3,200	670	1,230	6,761	763	1,091	3,110	620	1,190	6,774
China	715	4,120	1,633	247	92	6,807	720	4,040	1,530	249	85	6,624	732	4,360	1,547	254	76	6,969
Holland	3,000	1,677	1,897	378	281	7,233	2,891	1,346	1,376	352	202	6,167	3,091	1,426	1,382	361	219	6,479
Venezuela	1,032	29	4,936	50	160	6,207	983	25	4,866	42	150	6,066	631	21	4,911	38	154	5,755
Spain	3,150	161	1,734	230	290	5,565	3,167	165	1,728	210	280	5,550	3,107	191	1,836	182	301	5,617
Sweden	2,785	617	1,464	346	84	5,296	2,931	612	1,602	321	60	5,526	2,835	660	1,974	286	71	5,826
Belgium	2,139	775	1,232	623	124	4,893	2,266	720	984	590	103	4,663	2,589	659	969	492	107	4,816
Brazil	1,822	746	1,946	160	38	4,712	1,787	712	1,846	159	20	4,524	1,712	710	1,852	161	18	4,453
Denmark	2,116	714	1,343	303	22	4,498	1,915	639	1,605	181	14	4,354	1,840	672	1,644	236	186	4,578
Egypt	596	2,429	1,230	129	116	4,500	413	2,142	1,231	114	102	4,002	419	2,061	1,372	121	110	4,083
British Malay	622	289	2,712	63	118	3,804	917	230	2,308	62	110	3,627	640	276	1,796	72	90	2,874

* Foreign Oil Department, Henry L. Doherty and Co.

(Thousands of Barrels)

	1931						1932						1933					
	Gasoline	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Gasoline	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total	Gasoline	Kerosene	Gas and Fuel Oil	Lubricants	Miscellaneous	Total
Cuba	847	185	3,168	76	52	4,328	660	173	2,535	50	40	3,458	552	159	3,207	42	38	3,998
Phillipine Islands	887	586	1,863	80	110	3,526	697	560	1,824	74	102	3,257	687	548	1,901	72	96	3,304
Trinidad	112	60	2,613	36	241	3,062	110	61	2,690	31	236	3,128	115	71	2,415	32	221	2,854
Hawaii	869	110	2,053	45	76	3,153	801	106	1,996	45	72	3,020	906	127	2,024	46	69	3,172
Union South Africa	1,913	506	449	139	161	3,168	1,990	481	254	146	147	3,018	2,074	410	423	152	141	3,200
Switzerland	1,560	189	862	146	152	2,909	1,736	194	862	150	25	2,967	1,661	186	1,014	137	28	3,026
New Zealand	1,792	110	1,050	50	48	3,050	1,669	159	968	62	41	2,899	1,575	204	872	74	39	2,764
Czechoslovakia	2,301	229	340	190	38	3,098	2,001	220	337	190	32	2,780	1,670	217	432	171	30	2,520
Poland	701	1,029	424	279	490	2,923	643	944	328	357	452	2,724	605	720	546	252	421	2,544
Norway	849	305	1,049	75	49	2,327	847	277	1,335	69	48	2,576	840	264	1,625	72	272	3,073
Chile	809	71	1,800	48	55	2,783	410	64	1,415	32	18	1,939	463	71	1,581	42	28	2,185
Ireland	1,170	450	132	70	126	1,948	1,110	420	103	65	124	1,822	1,045	416	110	61	107	1,739
Panama Canal Zone	89	26	1,646	11	12	1,784	78	22	1,631	8	7	1,746	71	24	1,710	10	11	1,826
Uruguay	766	292	1,661	32	10	2,761	720	280	707	15	7	1,729	731	271	695	18	12	1,727
Austria	1,158	372	480	171	21	2,202	840	243	425	127	12	1,647	810	238	437	131	16	1,632
Algeria	1,060	370	110	87	80	1,707	930	360	36	21	70	1,417	1,070	271	263	91	30	1,725
Greece	425	163	601	53	36	1,278	402	160	589	51	32	1,234	360	137	756	41	26	1,320
Jamaica	149	53	876	6	11	1,095	144	47	1,008	7	5	1,211	148	42	998	8	9	1,205
Hungary	509	514	220	43	23	1,309	435	495	207	41	20	1,198	431	489	288	58	31	1,297
Colombia	289	59	820	21	19	1,208	281	64	5	20	81	1,061	331	56	647	41	71	1,146
Hong Kong	72	56	934	11	91	1,164	67	50	897	9	18	1,041	62	51	868	10	21	1,012
French Morocco	660	207	66	50	49	1,032	626	200	64	45	84	1,019	720	171	144	53	61	1,149
Iraq	145	176	555	36	164	1,076	128	153	530	33	156	1,000	181	163	620	48	180	1,192
Others	5,285	4,256	10,302	721	1,137	21,701	5,073	4,143	9,894	707	806	20,623	5,179	4,200	10,098	715	971	21,163
	558,217	113,697	601,374	47,685	76,839	1,397,812	523,994	103,288	522,239	38,089	133,261	1,320,871	536,332	107,937	543,714	40,649	137,659	1,366,291

Chapter III. Stabilization

Petroleum Stabilization in 1933

By Earl Oliver,* Ponca City, Oklahoma

The major development in stabilization of the oil industry during 1933 was the transition in the United States from state control to federal control in many of the functions that government is presumed to exercise. A brief review of the influences leading to that transition is given here to suggest its significance and to assist in forecasting its further development.

Bitumens were known to the ancients and have been applied to minor uses since earliest historic times, but it was not until after the discovery of oil in considerable quantities near Titusville, Pennsylvania, in 1859 that it was made the basis of extensive commercial undertakings.

In 1859 little was known about the origin of oil and gas, the nature of these deposits, and the physical laws that controlled their accumulation. Scientists soon began to study them, but 50 years or more of active oil-field development had elapsed before sufficient geological information had been accumulated to point the way toward efficient recovery of these products. In fact, only within the past five years has the function of reservoir energy become widely understood, yet it is a primary factor in oil recovery.

In the meantime, during the 75 years that have elapsed since the discovery near Titusville, this infant industry has developed into an industrial giant. In complete ignorance of their destructive effect, wasteful development methods were initiated in Oil Creek and these became industrial habits. These habits in turn became oil and gas law. Under that law vast sums of money have been expended, rights have become vested and development methods fastened on a great industry that not only bring upon it periodic demoralization but cause ruthless destruction of the nation's reserves of these important natural resources. This is occurring in the midst of a petroleum era when oil is essential to the nation's security, its industrial supremacy, and the personal convenience of every citizen. Its conservation, therefore, has become a question of grave national concern.

Conflict between Physical Facts and Oil Law

This destruction of an important natural resource and periodic demoralization of a vast industry can be halted only by readjusting oil

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* Chairman, Stabilization Committee, Petroleum Division A.I.M.E., 1934.

and gas law until it promotes oil-field development practices suited to the products handled. To indicate the readjustments that are necessary, it is desirable to summarize the elementary principles both of oil and gas accumulation and of oil and gas law.

Physical Facts

The origin of petroleum and natural gas still remains a subject of scientific controversy, although the most generally accepted theory is that they are related decomposition products of vegetable and animal organisms that were deposited in lagoons, estuaries, bays and lakes; that the resultant decomposition products were eventually forced into contiguous porous formations so constructed as to entrap them and prevent further migration.

Disregarding speculation as to origin, it is sufficient for our purpose to say that oil and natural gas deposits are now found together under pressure in porous sandstone, limestone or other entrapping media. This pressure is ascribed theoretically to a combination of influences, among which are hydrostatic head, weight of overburden, confined chemical reactions, and other more or less uncertain factors. Upon discovery of an oil pool this pressure usually corresponds somewhat approximately to the equivalent weight of a column of water reaching from the reservoir to the surface. If found at 500 ft., the original pressure is likely to be somewhat of the order of 200 lb. per sq. in. If found at 5000 ft. it may approximate 2000 lb. per sq. in., or the equivalent of one ton for each square inch.

The reservoir space occupied by the oil and gas is made up of pore spaces, usually microscopic in size; yet in the aggregate they frequently represent one-fourth to one-third of the total volume of the reservoir formation. Thus a sandstone of 25 per cent porosity is capable of containing 2000 bbl. of oil per acre-foot. If 10 ft. thick it could have an oil content of 20,000 bbl. per acre.

The geologic structures in which oil and gas have been trapped are innumerable in shape and extremely varied in size. Moreover, in most instances they were only partly filled with oil and contain, in addition, water and natural gas. In general, the three fluids collected in the common reservoir in the manner their respective weights would suggest. Water is found at the lowest point, oil at an intermediate elevation, with natural gas occupying the higher parts of the reservoir. To some extent, however, pressure modified these relationships as follows: Natural gas in the reservoir, corresponding to Boyle's law, occupies space in inverse proportion to the pressure; so that gas under 2000 lb. pressure occupies only 0.7 per cent of the space it would occupy at sea-level atmospheric pressure. Furthermore, in direct proportion to pressure exerted, oil is capable of holding natural gas in solution. Dissolved

gas renders the oil less viscous and enables it to pass through the minute pores of the reservoir formation with greater freedom. Retention of reservoir pressure during the period of oil recovery is important, therefore.

These segregated bodies of oil and gas vary greatly in extent and volume, dependent largely on the presence of source material and the shape, size, and porosity of the structure in which they were trapped. They range in size from a few acres to an accumulation like that of East Texas, which covers 120,000 acres. Most of the individual oil pools, however, do not exceed in area a few square miles.

These innumerable hidden oil and gas deposits have maintained the same status throughout geologic ages without movement, loss, or waste. They could be recovered with little waste. It is obvious, however, that as soon as a hole, providing a means of ready escape, is drilled into one

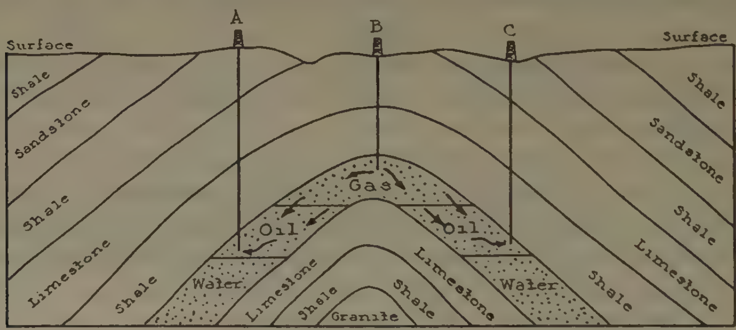

FIG. 1.—IDEAL OPERATION. (Reproduced from an article by the author in *Reports of American Bar Association*, Vol. 55.)

of these high-pressure reservoirs, with its intensely fluid content, a change of status takes place. Release of pressure through a hole drilled at any point into the reservoir permits the gas to expand. If the hole is advantageously located the expanding gas drives oil and water ahead of it through the porous reservoir formation toward the point of escape. By this means oil is driven out of the minute pores of sandstone or limestone into the well of the operator and a producing oil well is the result. On the other hand, if the hole is drilled into the part of the reservoir that contains gas only, the gas expands and escapes without driving oil ahead of it. Moreover, gas comes out of solution in the oil as the pressure is reduced. This tends to render the oil viscous and sluggish, difficult to move. Consequently most of it becomes lost to recovery in the microscopic pores of the reservoir formation.

Efficient and Inefficient Methods Contrasted

The modern conception of efficient recovery is to reinject that gas into the top of the structure that comes out with the oil lower down and

thus maintain a pressure on the reservoir until the oil content is as fully recovered as this recycling process will accomplish. See Fig. 1.

During the early life of the pool, under practices that have long prevailed, the oil moves freely because of the high pressure and its high fluidity, causing "gushers" or flowing wells, but as the pressure declines the wells decline in production. This explains the rapid decline that has constantly taken place in new oil fields. Unless there is also a hydrostatic head back of the oil that will drive it out when the gas pressure is depleted the oil ceases moving and the oil pool is abandoned, although the oil content is by no means exhausted. Laboratory tests of cores secured from holes drilled in abandoned pools have indicated that as much as 75 per cent or more of the original oil content remains in some of these pools, lost to recovery, through failure to utilize and direct this stored energy into more effective recovery. See Fig. 2.

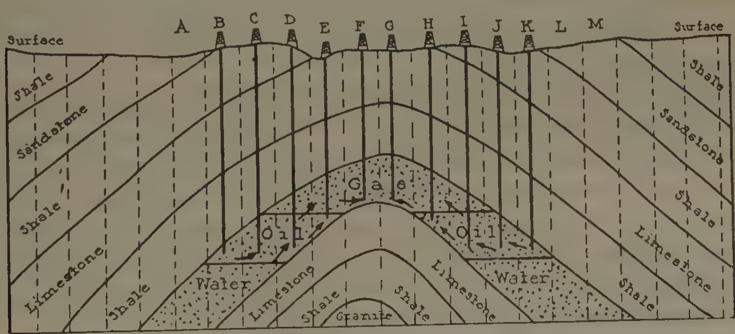

FIG. 2.—COMPETITIVE DEVELOPMENT. (Reproduced from an article by the author in *Reports of American Bar Association*, Vol. 55.)

Oil and Gas Law
The Capture Rule

Few of the foregoing facts were known when the Oil Creek discovery was made in 1859. In harmony with the law of real property in that state, the owner of land was assumed to own the content of his land. Accordingly leases were made by the landowners and wells were drilled by the lessees in the attempt to recover that content. It soon became apparent, however, that operations on one tract of land affected recovery on adjacent tracts. The courts found difficulty in adjudicating rights in litigation arising out of that condition.

Finally, 30 years after the beginning of the industry, in 1889, the Supreme Court of Pennsylvania, seeking analogous conditions in the law, evolved for oil and gas in place a new and impracticable type of ownership that has been responsible for destroying much of the nation's oil and gas resources. It gave legal sanction to development practices in the oil and gas industry that have made it extremely wasteful and unstable.

In Westmorland & Cambria Natural Gas Co. vs. DeWitt et al., 130 Pa. St. 235, that court said:

> Water and oil, and still more strongly, gas, may be classed by themselves, if the analogy be not too fanciful, as minerals *ferae natura*. In common with animals, and unlike other minerals, they have the power and tendency to escape without the volition of the owner. Their "fugitive and wandering existence within the limits of a particular tract is uncertain." They belong to the owner of the land and are part of it, and are subject to his control; but when they escape and go back into other land, or come under another's control, the title of the former is gone. Possession of the land, therefore, is not necessarily possession of the gas. If an adjoining, or even a distant, owner drills his own land, and taps your gas, so that it comes into his well and under his control, it is no longer yours, but his.

That opinion was rendered in connection with litigation over gas rights, but it was made equally applicable to oil and soon became a leading authority wherever the subject of oil and gas was discussed. Other courts enlarged upon it with variations until it evolved for oil and gas in place an ownership status the like of which has never been applied to any other species of property.

Legalizing reduction to possession of any object belonging to another makes ownership a nebulous thing. No incentive remains with the owner to care for and preserve the article for future enjoyment. Particularly is that true of articles so easily reduced to possession by another as are oil and gas in place. This ownership theory explains the rapid destruction in the United States of its oil and gas reserves. It is a type of ownership injurious alike to the public welfare and to the owner in that it imperils the thing to which it is applied.

In this instance it induces a wild scramble for oil and gas as soon as discovery is made. It supplies all the influences for immediate destruction of reserves that prompted slaughter of buffalo and wild pigeon in pioneer days. Nor did it even throw around this natural resource the regulation in reduction to possession that now characterizes game law. The property owner who complained to the court about injury being done him through wasteful development methods applied by others was advised that his only recourse was to go and do likewise. His only remedy was held to be achieved through drilling offsets. Thus the law forced immediate extraction regardless of market demand.

Apparently the courts, and even the oil industry at that time, were laboring under the misconception that the greatest direct damage done to other owners in a common pool by hasty and wasteful development methods on the part of any one owner was through his appropriating to himself more than his just share of the reservoir content. As a matter of fact, however, it now appears, in light of present scientific knowledge, the greatest direct damage done by that type of development is waste of reservoir energy. By that waste the total oil recovery is much reduced, and the cost of recovery is unreasonably increased.

Ownership in Common

It is true that in 1900 the United States Supreme Court in Ohio Oil Co. vs. Indiana, 177 U. S. 190, suggested for oil and gas in place a practical legal status which, if it had been pursued to its logical conclusion, would have avoided the injurious effect of the Pennsylvania opinion. In that case Justice White, later Chief Justice pointed out the distinction between animals *ferae natura* and oil and gas in place. He stated that things *ferae natura* are public property, and as such are subject to the absolute control of the state; on the other hand, that oil and gas in place are private property owned in common by those under whose lands the deposit lies, and as such the state has only a qualified control over them. He implied that that control, however, includes the authority to prescribe methods of development and operation that will prevent one common owner from doing injury or injustice to the other common owners or from taking more than his just proportion of the common supply.

The part of Justice White's opinion that recognized the right of the state to regulate development and production methods has been uniformly accepted as authority, but the part of his opinion that characterized oil and gas in place as the common property of those under whose lands the deposit lies, and as such, subject to just distribution among them, was consistently ignored.

To make effective the last mentioned phase of his opinion would have required legislative action on the part of the state specifying some practical standard of participation to supersede the unregulated capture rule. That in turn would have required a planned development and operation program in each local pool so that the specified standard could be complied with. The latter would not have been an unprecedented legal step. Governments long ago devised methods for handling property owned in common that insure justice and fairness to all the common owners. However, public understanding of the issues involved was not sufficient to promote the necessary legislation. Nor indeed has it yet developed to that point, although economic conditions are inevitably forcing the oil industry in that direction. Whether it will arrive before the nation's oil supply is completely dissipated is still an open question.

A Practical Standard of Participation

It is true that courts and writers have said repeatedly that the owner of the soil owns the oil and gas beneath its surface, and that is now declared to be the law in the majority of the oil-producing states. This would seem to be an acknowledgment of absolute ownership in the owner of the land of the oil and gas beneath the surface. That statement also appears to supply the much needed standard of participation in the common property that should supplant the unregulated capture rule.

Given that standard, petroleum engineers can readily evolve methods of developing and operating oil pools that will return to each landowner from the common supply an amount reasonably equivalent to the recoverable content of his land. This procedure would harmonize with the prevailing conception of ownership as applied to all other classes of property. If consistently enforced it would in time correct many of the ills of the oil industry.

Old Practices Perpetuated

However, the influence of practices and habits that have persisted from the beginning of the industry, and which were given legal sanction by the Pennsylvania decision of 1889, is so powerful that it has caused courts, even in states that have adopted the ownership in place theory, to follow the impracticable qualification propounded by the Pennsylvania court that "The oil in your land is yours; but if the owner of the adjoining land taps your oil so that it comes into his well and under his control, it is no longer yours, but his."

This peculiar concept of ownership has dominated the oil industry from its beginning 75 years ago. As each new oil discovery was made, oil was forced on the market in disregard of market demand. During the earlier years of the industry, discoveries were less frequent and the flood of oil was eventually absorbed after a period of industrial demoralization, but as oil finding and oil-recovery methods became more fully developed overproduction became chronic.

Federal Oil Conservation Board

Finally, on Dec. 19, 1924, notwithstanding that regulating oil production was considered to be a state function, President Coolidge constituted a Federal Oil Conservation Board consisting of four cabinet members to study the government's responsibilities and to enlist the industry in correcting the evils named. After extended investigation this Board concluded that the evils grew out of the capture rule, and that this could be overcome only through adoption of unit operation in the development of individual oil pools. This is a practical method of applying Justice White's suggestion made 25 years previously regarding ownership in common. It would enable efficient control and utilization of reservoir energy, and at the same time would afford a ready means of apportioning the common property among the several owners in proportion to the recoverable content of their respective land ownerships. It could be applied only in a modified form to pools already partly or fully developed, but could be applied in its entirety to new pools. The Federal Oil Conservation Board also unsuccessfully endeavored to promote an interstate compact to provide unity of action. Its various findings were incorporated in five reports issued during the years 1926 to 1932 inclusive.

Proration under State Control

While the Oil Board was unsuccessful in enlisting united action on the part of the several oil-producing states through the agency of a formal interstate compact, it did nevertheless assist in promoting individualistic action on the part of several states in curtailing production. So-called proration programs were initiated during 1927 in several oil-producing states. Under these the total aggregate production was designed to be kept within the limits of estimated market demand.

At first these proration activities were started as voluntary movements within the industry. Noncompliance promoted the passage of laws in several states setting up more or less restricted forms of proration, together with the agencies delegated to administer it. Compliance with the state curtailment program was vigorously resisted in the courts by certain types of objectors. But in all cases where the action of the administrative agency of the state was clearly within the intent of the statute, and the statute itself was clear and reasonable, the legislation of the state was upheld. In two states martial law was applied in the effort to maintain orderly efficient withdrawals, but this was due to the absence of legislation setting up an adequate due process under which orderly withdrawals could be made.

In this manner, through the proration laws, was gradually built up the first major modification in practice of the unregulated capture rule. In all cases where the issue was clearly drawn, the right of the state to regulate development and withdrawals was upheld. Continuation of chaos and demoralization in the oil industry was not due, therefore, to lack of authority in the state to regulate, but on the contrary was due to neglect of the state to enact practical legislation designed to that end.

The proration movement was launched under the guise of conservation, but the chief objective was to curtail production so that the price structure would not be unduly broken down. This was a proper motive in itself, since no industry can continue to run at a loss, but price demoralization was merely the surface manifestation of a deep-seated cause. Unfortunately, proration legislation was superficial in its aspects. It did not reach the cause. As a consequence administrative action also could be only superficial. Proration administration degenerated into an effort to regulate a vast industry through the use of temporary expedients designed for emergency application. No common principle by which individual rights could be determined ran through them. Property ownership became uncertain and obscure. As a result, violations were practiced with impunity, and proration broke down. Uncoordinated state control had failed in its objective.

Federal Oil Administration

This was the status when the Roosevelt administration took charge on March 4, 1933. With the breakdown of state control, the oil industry and the states alike looked to the federal government for relief. After passage of the National Industrial Recovery Act the President called a conference in the City of Washington to which the governors of the several oil-producing states and the oil industry were invited to send representatives.

Out of the several conferences that followed, an oil code was evolved. The Secretary of the Interior was named Oil Administrator. He was to be assisted by a Planning and Coordinating Board of 15 members, 12 of whom were to be nominated by the oil industry, and all were to be appointed by the President. The Secretary of the Interior also set up within his own official family a committee designated "The Petroleum Administrative Board" to assist him in his own personal responsibilities under the code. These two boards, working together under the direction of the Oil Administrator and in cooperation with the agencies of the several oil-producing states, have devised a system of curtailment of production, with the result that Mid-Continent 36° gravity crude oil advanced from 25¢ and less per barrel in May, 1933, to $1 per barrel in December, 1933. Chicago quotations on middle grade group 3 gasoline f.o.b. refinery increased from $2\frac{1}{8}$c per gallon to $4\frac{3}{4}$c on those respective dates. Corresponding increases took place elsewhere throughout the United States.

To that extent and in that manner has federal control superseded state control of the oil industry. It has been somewhat more successful in establishing temporary stability than were the several states. Like the states, however, the federal agencies have had legal authority to attack the problem only through superficial measures. Their attempts have been based on the capture theory of ownership and contain the inherent weaknesses of that theory.

This joint federal and industrial control, built as it has been on an unsound theory of ownership, has necessitated a vast, top heavy, complicated machinery of control that can scarcely endure as a permanent solution of the industry's problem. It is already giving evidence of breaking down under its own weight. On the other hand, the degree of success it has already attained as compared with the failure of state control will tend to invest the Federal Government with more permanent control over the industry than existed before March 4, 1933.

Although the present efforts of the Oil Administrator have necessarily been predicated on the capture rule, with its inherent defects, there is reason to believe that a degree of permanent federal control, as distinguished from state control, will result in the general adoption of more

efficient recovery methods. Prior federal studies have shown that tendency. Federal agencies are necessarily compelled to view the problem from a nationalistic outlook. Comparison of the methods of extraction in the United States with those of other enlightened nations clearly indicates that United States methods are not favorable to the national welfare. State agencies, on the other hand, are usually guided by the more restricted viewpoint of competition between states.

Basis of Federal Control

The legal basis on which federal control has heretofore been approached, apart from the N.R.A., has been the established right of the Federal Government to control interstate commerce. However, in view of the growing importance of petroleum products to the personal comfort and convenience of every citizen of the United States; to the economic welfare of its entire citizenship; to the transportation problems of its people; and to its safety during war, it is reasonable to expect that federal legislation looking toward effective conservation and utilization of this important natural resource could be sustained on other grounds. Failure of the several oil-producing states to enact suitable legislation to that end makes it imperative that the Federal Government do so in its own defense.

At the A.I.M.E. stabilization conference held in New York City on Feb. 22, 1934, Dean Roscoe Pound and Dean Henry M. Bates both expressed the opinion that the war power of the Federal Government gives it adequate constitutional authority to legislate control over development and operation of the oil industry, assuming that a suitable law is enacted to that end.

Objectives of Legislation

Effective legislation, among other objectives, would comprehend the following:

1. Developing suitable methods of balancing supply with demand.
2. Developing efficient utilization of reservoir energy.
3. Establishing a practical standard of participation.
4. Developing ownership control in local pools.

An essential step toward these objectives is recognition that each of nature's containers in which she has stored oil and gas should be regarded in engineering practice as a nondivisible unit entitled to peculiar and individual consideration. No two are alike in all respects. Therefore statutory enactments, to be effective, must be confined to general principles, leaving much discretion in the formulation of methods to administrative agencies.

Kettleman Hills Middle Dome Unit Plan*

By Joseph Jensen,† Los Angeles, Calif.

(Los Angeles Meeting, September, 1933)

When the legal holders of Government permits in the Middle dome of Kettleman Hills entered into an agreement on May 27, 1929, to suspend all drilling activities on five permits, covering portions of the Kettleman Hills Middle dome, until Jan. 1, 1931, and the owners of fee lands contiguous thereto assured Secretary Ray Lyman Wilbur, of the Department of the Interior, that they too would respect a drilling suspension for a period of a little more than 19 months, none of these interested parties realized that this was the first step in a chain of events that would culminate, more than four years later, in the formation of the Middle Dome Corporation for the development of the Middle dome area in a unit plan that would be the first unit plan to be approved by the California Regional Producers Committee and recommended to the President as a satisfactory unit plan, under Section 7 of Article III of the Oil Code, approved Aug. 17, 1933. Neither did they realize that more than two million dollars would be spent before oil or gas would be successfully and continuously produced from wells drilled on that Middle dome area. On Oct. 1, 1933, under the terms of the Middle Dome Agreement, the Middle Dome Corporation assumes control of activities and is responsible for the division of all products produced from the Middle dome area to members of the Middle Dome Corporation.

This Middle dome plan is the second successful unit plan developed in California in the past three years, the first being the Kettleman North Dome Association,[1] formed under the agreement of Jan. 31, 1931, for the unified operation and development of more than 12,000 acres of land on the North dome of the Kettleman Hills. All other unit plans discussed in the past four years in the state have not yet been completed, for one reason or another, but under Section 7 of Article III of the new Oil Code numerous plans of development, some of which may be unit plans, will be forthcoming within the next few months. There is much

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* Published by permission of J. H. Jenkins, Vice-President in Charge of Production, Associated Oil Co., San Francisco, Calif.

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[1] See also J. Jensen: Unit Operation in California. *Trans.* A.I.M.E. (1930) **86**, 71.

Unit Operation in California with Discussion of Kettleman North Dome Association. *Trans.* A.I.M.E. (1931) **92**, 80.

in the Kettleman Hills Middle Dome Agreement worthy of consideration by operators who are thus affected by the new Oil Code.

The discussions that resulted in the making of the Middle Dome Agreement extended over so long a period and were so entirely free from the usual pressure incident to making contracts that the agreement represents the rather mature deliberation of the engineers, lawyers and other parties who participated in its preparation and finally secured the approval of the form of the agreement from Harold L. Ickes, President Roosevelt's Secretary of the Interior. Nonetheless, it is true that work on the Middle Dome Agreement was more or less related to the drilling of the two wells in the field and was affected by developments in those wells.

Kettleman Hills Area

The general Kettleman Hills area has long been regarded with favor as a possible source of oil. Both the North dome and the Middle dome are clearly defined anticlines, separated by a distinct saddle, and extend along a general northwest-southeast trend in western Fresno and Kings counties, California. Most of the area was withdrawn from oil development in 1909 by President Taft, upon the recommendation of Dr. Ralph Arnold, then a geologist of the U. S. Geological Survey, and Dr. George Otis Smith, then Director of the Survey. Several wildcat wells were drilled on the North dome, whose discovery well proved to be Milham Exploration Company's Elliott No. 1, which blew in Oct. 5, 1928, when the hole was 7095 ft. deep. On the Middle dome, the first well drilled was that of the Bolsa Chica Oil Corporation, known as Downing No. 1. This well spudded in Jan. 29, 1924, and was drilled to a depth of 3502 ft. by Sept. 26, 1927. It found a small amount of heavy oil of 15° to 18° gravity. The well produced for a short time in 1928 at a 30 to 60-bbl. rate after the well had been plugged back to 2065 ft. Production was secured between 1749 and 2033 ft. in the Etchegoin formation of the Pliocene age.

On Jan. 3, 1931, the Petroleum Securities Co. spudded in its Burbank No. 1 well. This well, when tested for production on Dec. 13, 1931, at a depth of 9280 ft. (plugged back from 9332 ft.), flowed 1400 bbl. of 50° gravity oil, 1200 bbl. of water, through four $^{96}\!/_{64}$-in. beans, with a tubing pressure of 360 lb. and 34,000 M. cu. ft. of gas. The well was killed on Dec. 23, 1931, to make repairs. Thereafter work continued on the well until Sept. 7, 1932, when operations were suspended, without restoring the well to production.

Standard Oil Co. well No. 6-29V was spudded in Feb. 12, 1931. When the well reached a depth of 7885 ft., it was placed on an open-hole production test on Apr. 27, 1932. It made 1245 bbl. of 53.8° gravity oil, cut 45 per cent, tubing pressure 675 lb., casing pressure 1200 lb., gas

production 36,300 M. cu. ft. The well was killed May 24, 1932, and deepened to 8406 ft. When tested on June 3, 1932, it flowed 890 bbl. of oil, 360 bbl. of water and 25,000 M. cu. ft. of gas. The well died May 8, 1932, and thereafter for nearly a year a most difficult and successful piece of work followed. Happily, it resulted in the completion of the well on Apr. 20, 1933, producing 1072 bbl. of 55.5° gravity oil, 5 bbl. of water and 27,030 M. cu. ft. of gas, with a tubing pressure of 510 lb. and a casing pressure 935 lb. The well is plugged back to 7835 ft. and production is secured below the combination cementing point of the 7-in. casing at 7533 feet.

Discussions of Unit Plan

The first meeting to discuss a unit plan was held on March 11, 1931, following the passage on March 4, 1931, of the Unit Plan Amendment to Sections 17 and 27 of the Leasing Act of Feb. 25, 1920. At this first meeting a committee was appointed to draw up a form of agreement. Thereafter the subject was discussed more or less regularly through the fall and winter of 1931 up to April, 1932. When the Standard well went off production at that time no further action was taken. Upon the final completion of the Standard well in April, 1933, Secretary Ickes notified the permit holders in the Kettleman Hills that G. W. Holland, an attorney in the Department of the Interior, would be sent from Washington to work with the permit holders and the Standard Oil Co. in the formation of a unit plan. Mr. Holland, assisted by Robert Patterson of the U. S. Geological Survey, handled the situation with rare tact and skill. Following a month of negotiations in Los Angeles, Mr. Holland returned to Washington, accompanied by a committee of three, representing all interested companies in the Middle dome area. F. S. Bryant was chairman of this committee and E. H. Blanche as attorney and Joseph Jensen as engineer were members. Throughout all the meetings of the Middle Dome Committee, Mr. Bryant served as secretary and did all of the detail work for the committee. To him and the support of his employer, the Standard Oil Co., much credit is due for the formation and organization of the Middle Dome Corporation. Mr. Bryant was chosen as the first president of this new corporation.

In Washington the subcommittee was favorably received by Secretary Ickes, and negotiations were carried on through Nathan Margold, Solicitor of the Department, Mr. Holland and Herman Stabler, Chief of the Conservation Branch of the U. S. Geological Survey, assisted by Messrs. Soyster and Hines of his Division.

The general procedure adopted in preparing the different instruments was that followed in connection with the North Dome Agreement. All controversial matters were first assembled and worked out in the Middle Dome Agreement, to be executed by the corporation and its lease-owning

members. Routine and general matters of procedure that might be apt to change from time to time were included in the Articles of Incorporation and By-Laws of the Middle Dome Corporation, so that if necessary they could readily be changed in the future.

Under the March 4, 1931, Amendment to the Leasing Act of Feb. 25, 1920, unit plans may be organized after a discovery is made. The Secretary of the Interior is authorized to establish the outer boundaries of such a plan, and thereafter when any permit is within such a plan the Secretary of the Interior may issue a lease for the area of the permit so included in said plan, without further proof of discovery. Hence, in the beginning of the operation of such a plan, some lands will be classed as participating lands and others as nonparticipating lands. Under the Middle Dome Agreement the outer limits of the plan are bounded by a blue line and the participating lands are included within a red line, which is subject to change each year. This designation is different from that used in the Kettleman North dome plan, where the blue line is the outer limit of participation and the red line is an irreducible line, which protects all land within it from exclusion from participation. Whereas, in the North dome of Kettleman Hills all Standard fee lands were held intact in a separate body from those of the Kettleman North Dome Association, in the Middle Dome Agreement all Standard lands are included. The one unit plan covers the entire area.

Lands embraced in the Middle dome unit plan are shown on the accompanying map (Fig. 1). These lands are classified as shown in Table 1.

TABLE 1.—*Lands in Middle Dome Unit Plan*

Company or Lessee	Acres Inside Blue Line, Including those Inside Red Line	Original Participating Acres Inside Red Line	Original Percentage Participation
Standard Oil of California	7,900	580	49.57
Bolsa Chica Corporation	1,540	300	25.64
Petroleum Securities Co	1,300	150	12.82
Shell Oil Co	840	140	11.97
Associated Oil Co	640		
Robert Hays Smith	1,920		
Pacific Western Oil Co	400		
Total	14,540	1,170	100

PARTICIPATION ON ACREAGE BASIS

The most distinctive feature of the agreement is its provision relative to participation on an acreage basis. This is based upon a determination of the commercially productive or commercially nonproductive character

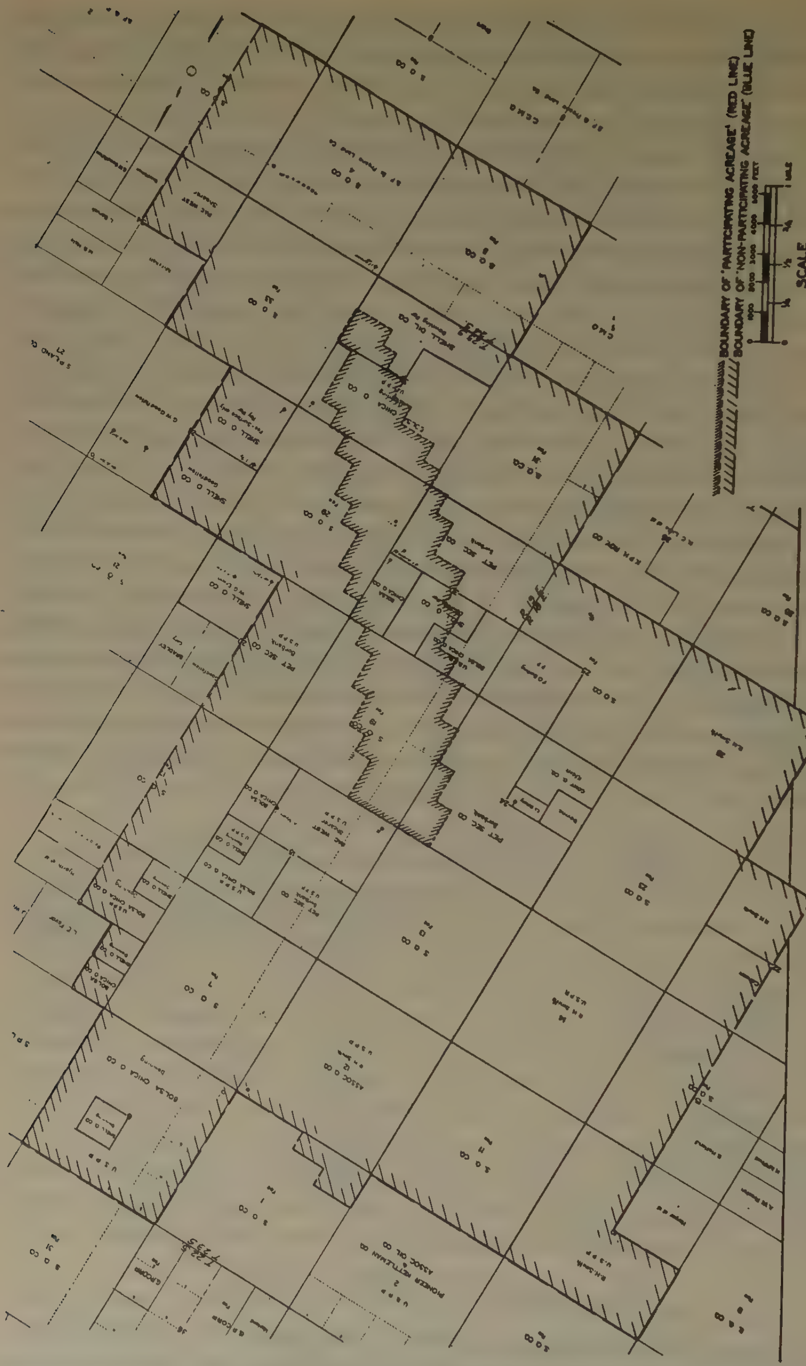

FIG. 1.—EXHIBIT A, MIDDLE DOME CORPORATION AGREEMENT OF AUGUST 1, 1933. LANDS IN MIDDLE DOME CORPORATION.

of the land as of the effective date of the agreement, which is Oct. 1, 1933. Whenever from time to time lands are classified either as participating or nonparticipating (that is, commercially productive or commercially nonproductive), retroactive adjustments in accounts are made back to the effective date of the agreement. To accomplish this, the Corporation will set the price of products distributed to the members so that, except for the item of interest on money for products delayed in distribution because of late classification, each acre of land finally determined to be productive on the effective date of the agreement shares equally with every other acre so classified and included within the red line. Except for interest, nothing is gained by early classification and, likewise, nothing is lost by delayed classification. Lands improperly included give back whatever has been credited to them and, likewise, are refunded the proportionate part of the expenses they have paid. To avoid an indéfinite question as to ownership of products distributed, the agreement provides that land once classified as participating cannot be classified as nonparticipating after five to seven years from the date of classification as participating lands.

In the matter of classification, a difficult question presents itself because nearly half of the land belongs to the Standard Oil Co. and half of the land belongs to the Government. As representation on the Board of Directors is based upon participating acreage held from time to time, the Standard would be able to control the Corporation. To avoid this, it has generously agreed that action by the Board on major problems can be taken only upon the affirmative vote of five of the seven directors of the Corporation. In land classification, even under this restriction, the Secretary of the Interior has the right to disapprove such action of the Board and to demand a reconsideration thereof in a hearing. If the dispute cannot be adjusted, the matter is to be settled by three arbiters, one chosen by the Secretary of the Interior, one chosen by the Board and one appointed by one of the judges of the Ninth Circuit Court of Appeals. In this manner every effort has been taken to protect the classification of lands and therefore the participation of each member, no matter how small that participation might be.

Naturally, a member holding nonparticipating land is interested in seeing it developed as early as possible in order to enjoy the benefits of participation. On the other hand, since participating members bear all of the expenses, it would be unfair to force the Corporation to drill unnecessary wells. Its effort should be to avoid the drilling of dry holes. The Corporation, therefore, is authorized to proceed to attempt to determine in a prudent and orderly manner the actual productive limits of the Middle dome area. The time, place and manner of carrying on drilling operations are to be determined by the affirmative vote of not less than five members of the board.

In the interest of conservation, the Secretary of the Interior has authority to alter or modify the rate of production from the lands to the end that waste shall be eliminated and to the end that the production of the Middle dome shall conform to the Corporation's fair and proper share of allowable production for the State of California.

Gas Conservation

The Agreement contains the most stringent gas-conservation clause contained in any operating agreement in existence in California. This paragraph reads as follows:

> That for the purpose of more properly conserving the natural resources of the lands embraced within this agreement, the production of gas shall at all times be limited to such gas as can be put to beneficial use, including but not being limited by or to gas used for repressuring, storage, fuel, sales and a reasonable and proper working surplus or field tolerance which may be blown to the air incident to and necessary in the proper operation of the wells and facilities used for treating and handling gas produced from said lands.

The Corporation will treat the wet gas as a part of its operations and will divide as products, to the members, crude oil, casinghead gasoline and dry gas.

Modification of Leases

Among other important benefits derived are the modifications of lease requirements, which the Secretary is authorized to make upon the formation of the unit plan. The first modification is that each and every lease issued and subject to the Agreement shall continue beyond the 20 years specified in the lease and until the termination of the plan. The second is the modification of all drilling requirements to those already outlined above. The third is the modification as to royalty requirements accruing to the United States on so-called B leases, or leases not at 5 per cent. The Agreement provided that this royalty rate shall be computed on the average daily gross oil production for each month for the corporation's participating acreage, as follows:

	Per Cent
Up to 2.24 bbl. per acre per day	12½
When over 2.24 and not over 4.48 bbl. per acre per day	16⅔
When over 4.48 and not over 8.96 bbl. per acre per day	20
When over 8.96 and not over 16.42 bbl. per acre per day	25
When over 16.42 bbl. per acre per day	33⅓

This scale applies during the time that the lands of the Middle Dome Agreement produce less than 3 per cent of the daily average rate of oil production of the entire Kettleman North dome field. Whenever the production of the Middle dome is more than 3 per cent of the North dome, these rates may be cut in half after notice and a hearing by the

Secretary of the Interior. In such a hearing the Middle dome operators are permitted to make a showing justifying the increase in production of the Middle dome in excess of 3 per cent of the daily average production of the North dome.

Lands are not transferred to the Corporation. Only the exclusive right to develop and operate the lands is given. Nevertheless, the Corporation does not plan to set up its own organization. First drilling will be done by the Standard Oil Co. and Petroleum Securities Co. and, possibly, later by the Bolsa Chica Corporation. Thereafter the Corporation may cause its field operations to be conducted by some member company under contract. In this way every effort will be made to reduce overhead to a minimum.

This original drilling by the three member companies named above proved to be the solution of one of the most difficult problems in connection with the organization of the unit plan. More than two million dollars was spent by the Petroleum Securities Co. and the Standard Oil Co. on their two wells. Some of the member companies did not feel, during the depression, that they were warranted or able to make so large a contribution toward the formation of a unit plan as would be necessary if they were required immediately to pay their proportionate share of the cost of these two wells. Furthermore, the Petroleum Securities Co. Burbank No. 1 well was not yet on production. Some work would be necessary on that well if an attempt were made to place it on production again. It was, therefore, decided to permit the Standard and Petroleum Securities to continue to drill and produce so as to recover their costs with interest at 4.5 per cent from the effective date of the Agreement and all other costs thereafter incurred with interest at 4.5 per cent until such items were repaid out of the production of oil, gas and gasoline. Thereafter, the Corporation will assume the operation of wells drilled by these companies, but until that time each member company will be in charge of wells drilled by it. Activities of these companies while drilling and operating are under the supervision of the Middle Dome Corporation. The casinghead gasoline plant already erected by the Standard Gasoline Co. will be used for the treatment of gas produced from all wells on the Middle dome and eventually it will be purchased by the Corporation.

While the Middle dome is not nearly so large as the North dome of Kettleman Hills, and probably thus far, according to the performance of its discovery wells, promises to produce a larger proportion of gas than most California fields, the Middle Dome Agreement represents a successful attempt at unitization and an honest effort to arrange for an equitable distribution between all of its members of the resources of the field.

Efficient Utilization of Reservoir Energy

A Contribution to the Problem of Petroleum Stabilization

By Joseph B. Umpleby,* Norman, Okla.

(New York Meeting, February, 1934)

The subject of reservoir energy and its efficient utilization has been well explored in many papers. The present effort, therefore, is limited to a summary of existing information combined with an emphasis of the probability that the relative importance of controlling factors will change with advancing knowledge. Consequently the necessity for flexibility in laws and regulations, inherent in the problem, is emphasized.

Definitions

Many terms have been widely used in the literature without having been specifically defined. For example, confusion exists in the use of "reservoir energy" and "gas energy." The latter is much more limited in meaning than the former. Other terms have been variously used. Consequently, I shall preface my remarks with definitions of a few of the more pertinent terms.

Reservoir energy is that force or forces, active or potential, that is native to the reservoir and has the power to move oil through the reservoir rock. The energy may result from expanding gas, from hydrostatic head, from the weight of overburden, or from any other source. Gas energy is the expansive power of gas when pressure is reduced. It is one type of reservoir energy.

An oil reservoir is that part of a geologic formation or formations in which oil occurs in commercial quantities wholly surrounded by nonproductive rock. The essence of this definition is effective separation rather than remoteness and under it oil reservoirs may be superimposed in the same oil pool. Conservation of reservoir energy means primarily its maximum use in the production of oil.

Unit operation is a plan of development and production, which embraces an entire oil reservoir under a unity of engineering control. It is distinct from unitization, which has to do with arrangements of organization and equities to make unit operation possible in areas of divided ownership.

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* Geologist and Petroleum Engineer.

Source and Ownership

There are three principal sources of reservoir energy as now viewed by engineers—the expansion of gas, the pressure of water and the weight of overburden. Probably of minor importance are fluid expansion, crystallization, earth movements, chemical precipitations, molecular rearrangement and perhaps others. The relative importance of these forces, both major and minor, is not known definitely. Only in recent years has the term "reservoir energy" displaced "gas energy" in recognition of the need for a broader term. The change was made primarily to include water drive, recognized as of great importance in many fields. More recently engineers and geologists are coming to suspect that an actual consolidation of the reservoir rock under the weight of overlying beds may be very important. It is also quite possible that we shall come to give much greater relative weight to factors now considered as of minor consequence. Certain it is that the three major factors now recognized have different relative importance in different pools and at different stages in the development of the same pool. This argues strongly for care in definition and flexibility in rules for control.

Of the three resources in an oil pool—oil, gas and reservoir energy—reservoir energy is set apart by its nature and its origin. In origin, it results from forces of compression acting on the entire contents of the reservoir. These may have many manifestations but in last analysis gravity, operating over a much wider area than the limits of the oil reservoir, is the cause. The existence of reservoir energy depends on the continuity of the confining beds, so that puncturing the container at any single point affects the whole. As reservoir energy is the force that moves the oil, changing its distribution changes the distribution of the oil.

Reservoir energy is more a conditioning factor than a recoverable resource. Its chief value results from work performed within the reservoir rather than work done at the surface. Such work as it can be made to do at the surface can be duplicated at relatively low cost, but no way is known to duplicate the work that it can be made to do in recovering oil from a natural reservoir.

The ownership of reservoir energy has received much study and discussion,[1] but the most concise statement available is by Earl Oliver, from which the following paragraph is quoted.[2]

> Oil and gas contained in each owner's land are physical objects subject to ready determination and distribution. Furthermore they have an established legal status. Each landowner has long been entitled by law to appropriate portions of them. The courts have recognized a type of ownership in relation to them. On the other hand this newly recognized propulsive force known as reservoir energy has no such legal

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[1] A symposium led by J. B. Umpleby, *Trans.* A. I. M. E. (1933) **103**, 22–33.

[2] E. Oliver. *Oil & Gas Jnl.* (Nov. 19, 1931).

status. Neither the legislature nor the courts has yet defined its ownership and they are, therefore, still free to fix a type of ownership upon this reservoir energy that is most beneficial to society. It is not gas. Neither is it oil. But it is a force that acts on both of them and may be separated from them. If the owner of gas and the owner of the oil are each permitted to appropriate their share of the oil and gas under conditions that do not injure others, they have no right to complain even though they are not allowed to exact tribute from others for use of their so-called shares of this reservoir energy. This reservoir energy is a force that works within the reservoir but should not be taken from it. It is a status to be maintained rather than a product to be divided.

Although there are several reasons for separating reservoir energy from oil and gas and for recognizing it as the common property of all owners in a pool, we must, nevertheless, clearly recognize that in most pools much of it is stored in the gas—both in gas dissolved in oil and in free gas. It is difficult to generalize as to the relative value in moving oil of the energy in the free gas as distinct from the energy in the dissolved gas. Under reservoir conditions a cubic foot of rock saturated with oil will hold around 40 per cent as much gas as the same rock free of oil. But in most fields the oil-producing area is more than two and one-half times as great as the free-gas area. Hence, it may be safe to conclude that in most reservoirs more gas is dissolved in oil than exists in the free state. It is certain, moreover, that the greater intimacy of dissolved gas with oil makes it more effective than free gas in moving oil through the reservoir rock. In reaching the general conclusion that far too little weight has been given to the relative volume and potency of dissolved gas as compared with free gas as an expulsive agent, the author has purposely omitted the effect of dissolved gas in reducing the viscosity of oil. This effect is of tremendous importance, but it is a phenomenon distinct from energy relationships.

It is fundamental that in puncturing an oil reservoir there is a movement of all fluid and gas therein toward the point of reduced pressure. It is also fundamental in oil reservoirs that below some critical point a further drop in pressure causes gas to come out of solution. This has the dual result of decreasing the effective energy available and (because of the lubricating effect of dissolved gas) increasing the need for energy. Furthermore, a large amount of oil in any reservoir adheres to the sand grains and is not recoverable. Thus, if gas is withdrawn from the gas-filled portion of a reservoir, oil migrates into the gas area and a further amount is lost to recovery through adhesion. These and many other factors argue convincingly for postponing gas production until commercial oil production has been completed.

It follows that if we consider reservoir energy as common property and make maximum use of it we must provide for the early production of oil and require the deferred production of gas. It is fairly certain, because of the amount of gas dissolved in oil, that oil pools on the average

contain enough gas in excess of that in free-gas areas to more than compensate, under modern practice, for the losses of gas incident to oil production; therefore the requirement of the owner of free gas need be only a loss through delayed income and not a loss through diminished resource. Fairness requires that the owner of free gas be compensated fully for such delayed income and that ultimately there be available to him the full amount of gas originally in his property. The analysis to this point may be summarized as follows:

1. An oil reservoir contains three resources—oil, gas and reservoir energy.

2. The oil and/or gas in a tract belong to the owners of the mineral rights in that particular tract.

3. The reservoir energy should be legally recognized as common property of all owners of mineral rights in the reservoir.

4. The commercial extraction of oil should precede the commercial extraction of gas.

5. The owner of free gas should be compensated for deferred income and all of his gas ultimately made available to him, but he should not be compensated for the use of energy stored in it.

This analysis may not be fully convincing, but the endeavor has been made to present the case for the common ownership of energy as strongly as the facts permit.

Let us, therefore, examine the alternative view; namely, that reservoir energy has value because it can be made to do work and therefore should be divided. We have seen that not only the gas-filled, but also the oil-filled, parts of the reservoir contain gas energy. A unit volume of the former contains more gas and hence more gas energy than a unit volume of the latter, but we lean to the opinion that the smaller amount, because of its more intimate association with the oil, is more effective than the larger amount as an expulsive force. How shall we distribute value between them?

We have seen that overburden may be an important energy factor. Does the farmer who has sold all his mineral rights still have an equity in the underlying oil reservoir because his land continues to exert pressure on its contents? How shall we allocate value between this force and the expulsive force of gas?

Water drive is an important factor in most oil pools. Take the Wilcox sand as an example. It crops out as the Simpson formation in the Arbuckle and Wichita Mountains of Oklahoma and as the St. Peters sandstone in Wisconsin. Down from its outcrop it yields artesian wells in great numbers. Water moves easily through it and exerts an important pressure around the edge of every oil field where it produces. Possibly in the Seminole pools this hydrostatic head is more important than gas pressure in producing oil. Shall we share the energy value of this water

with owners of water in contact with the oil, or shall we confine it to owners along the outcrop where water enters the formation? What of the owner of other land beneath which the water moves? How shall we allocate energy value between water, overburden, free gas and dissolved gas? The already insoluble problem will be further complicated if advances in knowledge raise some of the other factors from minor to major importance or reveal new factors.

Of the two alternatives, common ownership of reservoir energy or divided ownership, the former is as fully supported by established facts and recognized phenomena as is the latter and is infinitely easier of just application. Its acceptance would simplify the conservation movement, greatly increase the extraction of oil and, through reduction of necessary costs, benefit all those interested in the petroleum industry either as producer or consumer.

Efficient Utilization

The efficient utilization of reservoir energy involves many engineering factors, such as: spacing of wells, distribution of wells on structure, maximum withdrawal from wells with low energy consumption, the maintenance of reservoir pressure, careful study and control of the rate of withdrawal, and, in general, lengthening the flowing life of wells by careful selection of methods and equipment.

The most advantageous spacing of wells is different for different reservoirs and for different parts of the same reservoir. Well spacing involves cost factors on the one hand and factors of oil migration on the other. Costs may be fairly well determined in advance of development but recovery factors must be based, in large part, on experience in working with the particular reservoir. Recovery factors involve sand thickness, sand saturation, the amount of gas both free and dissolved, the consistency of the oil, water conditions and size and character of sand grains. From a practical standpoint the relative importance of these several factors is never the same in different reservoirs. Hence any plan of well spacing should be subject to revisions as development proceeds and information accumulates. In general, wide spacing should be adopted at the start and subsequently reduced in the light of local experience.

Any plan of distribution of wells should be subject to similar revisions. In general, well density should be greatest along the zone about midway between edge water and the central gas cap. But in some structures edge water is static and others do not have a central gas cap. Moreover, there are all gradations between the Bradford field where no edge wells have gone to water in 50 years of production, and some of the Mexican fields where a well may be flowing oil at the rate of 30,000 bbl. in the forenoon and change to an equal amount of water in the afternoon of the same day. There are all gradations between a well defined gas cap, as at

Hobbs, N. M., and the total absence of a gas cap, as at Seminole, Okla. In most fields, however, for instance Oklahoma City and East Texas, water encroaches at a moderate rate and is an important factor in expelling oil from the reservoir. Gas probably is omnipresent with oil and exerts an important expulsive force. Even where there is no area of free gas some wells produce more gas with each barrel of oil than others. As good operation calls for the least possible expenditure of gas energy per barrel of oil produced this also should be a determining factor in well distribution. These variables all argue for flexibility in operation schedules. In general, early wells should be located with the idea of defining the productive area and determining reservoir characteristics. Subsequently, few wells should be drilled in the central gas area and few near the water contact.

Best practice calls for the lowest reasonable expenditure of reservoir energy per unit of production. As expanding gas in most fields is an important expulsive force the amount of gas accompanying each barrel of oil, designated the gas-oil ratio, becomes one measure of efficiency. Another measure of efficiency is maintenance of pressure within the reservoir. In some fields this is maintained by the encroachment of water at the edge of the reservoir and efficiency dictates that oil be removed only as fast as water crowds in to take its place. This is particularly important because dissolved gas makes oil more fluid and hence more easily moved through the minute interstices of the reservoir rock. The amount of gas dissolved in oil depends not only on available gas but also on existing pressure. Furthermore, gas once premitted to come out of solution cannot be replaced, because in the absence of agitation diffusion is so slow as to be negligible. For these reasons pressure maintenance is of transcendent importance. It is particularly noteworthy that in the Hobbs field, where the open-flow potential is said to be around one million barrels a day, only 33,000 bbl. a day can be produced without causing a noticeable drop in pressure. Similarly, in East Texas, where stated potential is nearly eight million barrels, the ideal daily withdrawal is about 450,000 bbl. I suspect we will find that in most if not all fields there is a maximum daily output far below the open-flow potential, but still substantial in amount, at which a reservoir can be produced to ultimate exhaustion without a noteworthy drop in reservoir pressure. The probable reason for this is that water encroaches and overburden settles at a definite rate for each situation. It is by no means certain, however, that other factors do not enter. Thus, it is not improbable that the maintenance of reservoir pressure may come to be considered the all-important measure of efficiency. Should it come to be required that reservoir pressure be maintained within definite percentage limits, an operator's only means of increasing daily output would be by introducing something into the reservoir as excess oil is removed. The

technique for this is well established through repressuring and water-flooding operations.

Room for Increased Efficiency

It has long been recognized that reservoir energy is exhausted under current practices long before the reservoir is drained of oil. Petroleum mining at Wietze and Pechelbronn shows that after half a century of production, at a time when wells had almost ceased to pay a profit, approximately 85 per cent of the original oil remained in the sand. There is absolutely no doubt about this percentage because many thousands of tons of sand have been mined and have yielded more than 99 per cent of this remaining 85 per cent. Core studies and porosity determinations in many fields indicate comparable situations in this country. The author has several times expressed the belief that on the average recovery does not exceed one-quarter of the oil actually in the sand. But, whether the correct figure be one-quarter, or one-half, or even three-quarters, there is a substantial reward for increased efficiency in the use of reservoir energy. Much improvement in recovery has been made in recent years through advances in engineering technique and cooperative action, but full efficiency cannot be attained until each oil reservoir is developed and operated as an indivisible unit, the inherent characteristics of which fully determine procedure.[3]

Conclusions

It is concluded that to attain maximum efficiency in the use of reservoir energy effective recognition must be given to certain fundamental concepts. The evidence is conclusive that each oil reservoir should be developed and operated as an indivisible unit. The attainment of this end will be greatly facilitated if ownership of oil and gas is legally based on acreage content, and if reservoir energy is legally recognized as a common attribute to be used for the common good and not a resource to be divided. Such recognition appears both feasible and just. With these basic rights established, a simple and effective approach to the conservation problem might be to prohibit the drilling of wildcat wells except on unitized blocks, leaving fully to the owners in interest the details of unitization; subject, however, to governmental approval of the plan. In view of the variable characteristics of oil reservoirs that permeate all phases of the problem, laws and regulations must be sufficiently general to permit of wide flexibility in operating procedure. The necessity of flexibility cannot be too strongly urged. A lack of necessary flexibility constitutes the chief danger in regulatory measures.

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[3] The writer attempted to summarize current ideas on this subject in a paper published by the World Petroleum Congress, organized by the Institution of Petroleum Technologists, South Kensington, London, July, 1933.

Chapter IV. Production

Introduction

By Frank A. Herald,* Fort Worth, Texas

Through the generous cooperation of the authors of the papers in this chapter, a great wealth of fundamental data is being made available. The same plan of securing and submitting data will be carried forward next year, with the hope of making a nearer approach to complete presentation of the data contemplated in the plan.

In order to conserve space, we are printing below such footnotes as have general application to Table 1 in the papers in this chapter:

Footnotes to Column Headings

Table I

[a] In areas where both oil and gas are produced, unless gas is marketed outside the field, such areas are included in column headed "Oil." Manufacture of casinghead gasoline and carbon black is interpreted as outside marketing of gas.

[b] Production per acre is determined by dividing into the number of barrels of oil the sum of the number of acres assigned to "Oil" plus such number of acres of the total assigned to "Oil and gas" as represents the portion thereof occupied by oil.

[c] Wells producing both oil and gas are classified as "Producing oil only" unless gas from them is marketed off the lease.

[d] W, water; G, gas; A, air.

[e] Bottom-hole pressures are preceded by "e." All other figures represent pressures at casinghead with well closed.

[f] P, paraffin; A, asphalt; M, mixed.

[g] Cam, Cambrian; Ord, Ordovician; Sil, Silurian; Dev, Devonian; Mis, Mississippian; MisL, Lower Mississippian; MisU, Upper Mississippian; Pen, Pennsylvanian; Per, Permian; Tri, Triassic; Jur, Jurassic; CreL, Lower Cretaceous; CreU, Upper Cretaceous; Eoc, Eocene; Olig, Oligocene; Mio, Miocene; Pli, Pliocene.

[h] S, sandstone; SH, sandstone, shaly; Ss, soft sand; H, shale; L, limestone; LS, limestone, sandy; C, chalk; A, anhydrite; D, dolomite; Da, arkosic dolomite; GW, granite wash; P, serpentine.

[i] Figures are entered only for fields where the reservoir rock is of pore type. Figures represent ratio of pore space to total volume of net reservoir rock expressed in per cent. "Por" indicates that the reservoir rock is of pore type but said ratio is not known by the author. "Cav" indicates that the reservoir rock is of cavernous type; "Fis," fissure type.

[j] A, anticline; AF, anticline with faulting as important feature; Af, anticline with faulting as minor feature; AM, accumulation due to both anticlinal and monoclinal structure; H, strata are horizontal or near horizontal; MF, monocline-fault; MU, monocline-unconformity; ML, monocline-lens; MC, monocline with accumulation due to change in character of stratum; MI, monocline with accumulation against igneous barrier; MUP, monocline with accumulation due to sealing at outcrop by asphalt; D, dome; Ds, salt dome; T, terrace; TF, terrace with faulting as important feature; N, nose; S, syncline.

[k] Information will be found in text as indicated by symbols; A, name of author, other than above, who has compiled the data on the particular field; C, chemical treatment of wells; G, gas-oil ratios; P, proration; U, unit operation; R, references; W, water; O, other information.

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* Consulting Petroleum Geologist and Engineer; Vice-chairman for Production, A. I. M. E. Petroleum Division, 1933 and 1934.

Interpretations

The following paragraphs from my Circular to Authors, dated July 7, 1933, will facilitate a proper interpretation of the data presented by the various authors.

As to each space in the tabulation, it is either (1) not applicable, (2) the proper entry is not determinable, (3) the proper entry is determinable, but not determinable from data available to the author, (4) the proper entry is determinable by the author. In spaces not applicable, the author will please draw horizontal lines; in spaces where the proper entries are not determinable, the author will please insert x; in spaces where the proper entries are determinable but not determinable from data available to the author, the author will please insert y; in spaces where the proper entries are determinable by the author he will, of course, make such entries. Generally, y implies a hope that in some future year a definite figure will be available.

Inability to determine precisely the correct entry for a particular space should not lead the author to insert merely y. Contributions of great value may be made by the author in many cases where entries are not subject to precise determination. In such cases the author should use his good judgment and make the best entry possible under the circumstances. For many spaces, the correct entries represent the opinion of the author (for example, "Area Proved") and in such cases the entries need not be hedged to such extent as in cases where the quantities are definite yet can be ascertained only approximately by the author.

In cases under definite headings but where figures are only approximate, the author may use x. For example, if the total production of a field is known to be between 1,800,000 and 1,850,000, the author may report 1,8*xx*,*xxx*; or if the production is between 1,850,000 and 1,900,000, the author may report 1,9*xx*,*xxx*.

Where a numeral is immediately to the left of x or y, such numeral represents the nearest known number in that position.

As to quantity of gas produced from many fields the question will arise as to whether the figures should include merely the gas marketed or should include also estimates of gas used in operations and gas wasted. Although rough approximations may be involved, our figures should represent as nearly as possible the total quantity of gas removed from the reservoir.

While we have not provided a column for showing the thickness of the productive zone, generally the difference between average depth to bottoms of productive wells and average depth to top of productive zone will represent approximately the average thickness of the productive zone. For fields where this is not true because of unusually high dips, or for other reasons, it is suggested that the authors indicate in their texts the approximate average thickness of the productive zone.

The figure representing net thickness of producing rock should correspond to the total of the net portions of the producing zone which actually yield oil into the drill hole. It is recognized that for some fields the authors can make only rough guesses—so rough that figures would be of no value. In such cases the authors should enter either x or y, whichever is more appropriate. Production per acre-foot will have to be treated, of course, in the same manner for the corresponding fields.

Please note that the heading "Number of Dry and/or Near-dry Holes" is intended to cover only such holes as are within the limits of the defined fields. The holes entered here will be distributed in Table 2 by counties and by depths.

Oil and Gas Development in Arkansas

By B. C. Craft,* Baton Rouge, La.

(New York Meeting, February, 1934)

Oil and gas development in Arkansas during the year 1933 has been marked by considerable wildcat drilling, considering the overproduction prevalent in the oil industry.

Arkansas showed an increase in drilling operations during 1933. There were 45 completions from 10 counties resulting in 7 oil wells and 38 dry holes, compared with 37 completions resulting in 4 oil wells and 33 dry holes during 1932. Miller County continued to be the most active area, with 18 completions resulting in 3 oil wells and 15 dry holes. Extensive exploration around the Miller County field has more definitely established the producing limits. It has confirmed the belief that produc-

Table 1.—*Oil and Gas Production in Arkansas*

Line Number	Field, *County*	Age in Years to End of 1933	Area Proved, Acres		
			Oil	Gas	Total
1	Mansfield, *Scott, Sebastian*	32	0	3,000	3,000
2	Massard Prairie, *Sebastian*	30	0	3,000	3,000
3	Kibler,[1] *Crawford*	19	0	3,100	3,100
4	Williams, *Crawford*	16	0	4,000	4,000
5	Irma, *Nevada*	13	640	0	640
6	El Dorado, *Union*	13	8,160[3]	0	8,160
7	Clarksville, *Johnson*	13	0	2,560	2,560
8	Alma, *Crawford*	12	0	1,640	1,640
9	East El Dorado,[2] *Union*	12	1,490	0	1,490
10	Stephens, *Columbia, Ouachita*	12	3,010	0	3,010
11	Smackover, *Ouachita, Union*	12	25,480[4]	0	25,480
12	Bradley, *Lafayette*	9	80	0	80
13	Lisbon, *Union*	9	2,640	0	2,640
14	Rainbow City, *Union*	7	1,480[5]	0	1,480
15	Mt. Holly, *Ouachita*	5	90	0	90
16	Urbana, *Union*	4	250	0	250
17	Lavaca, *Sebastian*	4	0	3,000	3,000
18	Shibley, *Crawford*	4	0	2,560	2,560
19	Miller County, *Miller*	2	80	0	80
	Total		43,400	22,860	66,260

[1] Includes sec. 10 area or Kibler Extension.

[2] Includes the Woodley pool.

[3] Productive acreage of the Nacatoch sand is estimated at 7740 acres, the Ozan 400 acres, and the Tokio 400 acres (figures courtesy W. C. Spooner).

[4] Producing acreage of Nacatoch sand is estimated at 18,230 acres; the Meakin, 9600; the Graves, 6530, and the Tokio 9125 acres (figures courtesy W. C. Spooner).

[5] Productive acreage for the Crain sand is estimated at 1200 acres and the Gregory at 1000 acres (figures courtesy W. C. Spooner).

* Assistant Professor of Petroleum Engineering, Louisiana State University.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933
1								5,150[6]	30.5	30	0.2
2								5,444[6]	296.5	310	0.5
3								74,849	971	1,188	20
4								7	7	7	7
5	5,002,460	386,065	231,000	550	7,816	521	13				
6	43,967,148	875,740	775,895	2,100	5,388	215	8				
7								10,510	2,286	2,322	15
8								7	7	7	7
9	8,293,982	228,685	177,720	485	5,566	795	7				
10	5,101,275	189,915	144,305	650	1,694	211	3				
11	336,054,625	9,698,625	8,892,655	23,860	13,189	527	11				
12	186,705	0	0		2,333	466					
13	5,982,625	183,605	150,345	415	2,266	68	2				
14	10,232,845	654,695	497,225	1,290	6,914	276	19				
15	117,085	0	0		1,301	185					
16	1,310,125	237,720	484,810	2,800	5,240	524	254				
17								8	8	8	0.6
18								7	7	7	7
19	110,210	5,000	105,210	740	1,377	137	148				
	416,359,085	12,460,050	11,459,165	32,890				96,953	3,584	3,850	36.3

[b] Footnotes to column headings and explanation of symbols are on page 175.
[6] Estimated total production.
[7] Included with Kibler.
[8] Included with Massard Prairie.

Line Number	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933		Pressure, Lb. per Sq. In.[e]		
	Completed to End of 1933	During 1933		At End of 1933				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of	
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing			Flowing	Pumping		1932	1933
1	9	0	0	0		9	9	1,553	1,125–2,010			315	145	140
2	90	0	0	0		48	48	1,724	1,296–2,180			220–265	25	25
3	40	0	0	0		30	30	2,054	1,310–2,175			220–260	46	40
4	45	0	0	0		45	45	2,387	1,510–2,375			220–265	65	60
5	142	0	0	19	43		43	1,179	1,150	0	43	x	0	0
6	1,112	0	10	6	250		250	2,177	2,100–2,550 –2,935	0	250	x	0	0
7	12	0	0	0		9	9	2,838	1,061–2,275 –3,066			345–690 –1,275	105–1,000	100–950 75
8	33	0	0	0		25	25	2,538	1,668–2,600			330–420	80	
9	180	0	5	4	71		71	2,176	2,175–2,890	0	71	x	0	0
10	298	1	2	10	196		196	2,135	1,500–2,095	0	196	x	0	0
11	3,719	2	63	31	2,049		2,049	2,109	2,050 [9, 10]	0	2,049	960–1,100	0	0
12	5	0	0	0	0	0	0	2,790	2,785			x	0	0
13	356	0	20	8	186		186	2,136	2,100	0	186	x	0	0
14	189	0	0	6	66		66	3,120	2,800–3,016 –3,200	0	66	x	0	0
15	6	0	0	0	0	0	0	2,813	2,800			x	0	0
16	22	1	0	0	13		13	3,560	3,525	1	12	y	y	y
17	16	0	0	0		16	16	2,972	2,900			270	265	260
18	6	0	0	0		6	6	1,231	1,150			200	135	130
19	5	3	0	0	5		5	2,929	2,919	0	5	x	y	0
	6,285	7	100	84	2,879	188	3,067	2,338		1	2,878			

[9] Includes the Meakin sand productive from 2250 to 2300 ft. and the Graves sands productive from 2350 to 2450 ft.
[10] Includes the 2600-ft. or Third sand found from 2550 to 2650 ft. and the Deep sands found from 2700 to 2900 ft.

TABLE 1.—(*Continued*)

Line Number	Character of Oil Approx. Average during 1933: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas: Approx. Average during 1933: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average, Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1						893	0	Atoka	Pen	S	Por	210	D	9	Atoka	2,635
2						892	0	Atoka	Pen	S	Por	150–90	A	1	Atoka	3,175
3						895	0	Atoka	Pen	S	Por	30–36	A	2	Atoka	3,002
4						893	0	Atoka	Pen	S	Por	30–36	A	16	Atoka	2,754
5	16	14	15	2.7	A			Nacatoch	CreU	S	Por	15	AF	25	Trinity	3,000
6	38	30	34	1.0	M			[11]	CreU	S	Por	25	Af[18]	155	Trinity	3,396
7						895	0	Atoka	Pen	S	Por	19–15–34	A	5	Atoka?	5,597
8						893	0	Atoka	Pen	S	Por	30–36	A	8	Atoka	3,077
9	21.5	18	20.5	2.4	A			Nacatoch[12]	CreU	S	Por	7	T[18]	39	Trinity	3,073
10	14–30	12–30	29	2.87–1.63	A P			Buckrange[13]	CreU	S	Por	15–8	TF[18]	44	L. Trinity	4,502
11	30	15	21	2.2	A M			[14]	CreU	S	Por	25	DS[19]	357	L. Trinity[20]	7,255
12								Buckrange	CreU	S	Por	5	T	4	Trinity	3,532
13	38	28	33	1.25	M			Nacatoch	CreU	S	Por	33	A[18] S	18	Trinity	3,509
14	35.5	21.6	29	0.80	P			[15]	CreU	S	Por	16–18	T	113	L. Trinity	4,533
15								Glen Rose[16]	CreL	S	Por	7	ML	14	Trinity	3,378
16	20	19	19.5	2.1	A			L. Trinity	CreL	S	Por	10	N	29	L. Trinity	4,501
17						893	0	Atoka	Pen	S	Por	10	A	0	Atoka	3,235
18						893	0	Atoka	Pen	S	Por	y	A	2	Atoka	2,380
19	34	31.6	32	1.2	M			L. Trinity	CreL	S	Por	10	ML[18]	21	L. Trinity	4,519

[11] Nacatoch is principal producing rock. Others are Ozan, Meakin, Tokio, "2900-ft. sand."
[12] One well produces from Tokio.
[13] Nacatoch also producing, but not important.
[14] Nacatoch, Ozan[9] and Tokio.[10]
[15] Tokio, 2800-ft., Upper Cret., Crain, Red Series and Gregory.
[16] Mt. Holly sand.
[17] Includes dry holes drilled in defining the producing limits of the field.
[18] Lenticularity has localized the oil.
[19] Structure in Louann area is a terrace and fault. Ds refers to Norphlet area.
[20] Abandoned in salt.

tion would be confined to a very small area due to the lenticular nature of the sand.

Oil production in Arkansas for 1933 was 11,459,165 bbl., a decline of 8 per cent from that of 1932. The normal decline of the old fields was partly offset by increased production at Urbana and Miller County fields. Unless unexpected discoveries are made, the production will continue to decline during 1934.

There is little of importance to be added to the production record of the north Arkansas gas fields. The combined open flow for this area is estimated at 375,000,000 cu. ft. Owing to the decline in rock pressure in many fields and a small maximum daily production of 36,300,000 cu. ft., it is quite reasonable to assume that this area will be rather inactive during 1934.

TABLE 2.—*Summary of Drilling Operations in Arkansas*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934										Completed during 1933						Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes									Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes					Productive Wells (For Details, See Table 1)	Within Fields	Exploratory
	Total Depths, Ft.								Total		Total Depths, Ft.				Total			
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000			1000–2000	2000–3000	3000–4000	4000–5000				
Arkansas	2	5	4	2	0	0	0	0	13		0	0	0	0	0			1
Ashley	0	0	5	11	1	0	0	0	17		0	0	0	0	0			0
Benton	1	4	2	0	0	0	0	0	7		0	0	0	0	0			0
Boone	1	0	2	0	0	0	0	0	3		0	0	0	0	0			0
Bradley	1	2	4	14	1	0	0	0	22		0	0	0	0	0			0
Calhoun	0	3	7	15	1	0	0	0	26		0	0	0	0	0			0
Carroll	0	0	2	0	0	0	0	0	2		0	0	0	0	0			0
Chicot	1	0	3	5	0	0	0	0	9		0	0	0	0	0			0
Clark	6	11	4	2	0	0	0	0	23		0	0	0	0	0			0
Clay	1	6	0	0	0	0	0	0	7	1[1]	0	0	0	0	0			
Cleburne	0	1	0	2	1	0	0	0	4		0	0	1	0	1			0
Cleveland	2	4	3	6	0	0	0	0	15		0	0	0	0	0			0
Columbia	3	9	45	28	1	0	0	0	86	202	1	0	0	0	1	1		2
Conway	0	2	2	2	0	0	0	0	6		0	0	0	0	0			1
Craighead	0	5	2	0	0	0	0	0	7		0	0	0	0	0			0
Crawford	0	1	39	5	0	0	0	0	45	127	0	0	0	0	0			0
Crittenden	1	1	3	2	0	0	0	0	7		0	0	0	0	0			0
Cross	1	0	1	1	0	0	0	0	3		0	0	0	0	0			0
Dallas	1	7	10	2	0	0	0	0	20		0	0	0	0	0			0
Desha	1	1	0	3	0	0	0	0	5		0	0	0	0	0			0
Drew	2	8	9	8	0	0	0	0	27		0	0	0	0	0			0
Faulkner	0	1	1	3	0	0	0	0	5		0	0	0	0	0			0
Franklin	1	5	7	1	0	0	0	0	14	5[1]	0	0	0	0	0			0
Garland	2	2	0	1	1	0	0	0	6		0	0	0	0	0			0
Grant	1	7	14	1	0	0	0	0	23		0	0	0	0	0			0
Greene	0	2	1	0	0	0	0	0	3		0	0	0	0	0			0
Hempstead	9	7	22	1	0	0	0	0	39		0	0	0	0	0			1
Hot Spring	0	10	0	0	0	0	0	0	10		0	0	0	0	0			0
Howard	4	10	0	0	0	0	0	0	14		0	0	0	0	0			0
Independence	0	3	2	0	0	0	0	0	5		0	0	0	0	0			0
Jackson	4	2	1	0	0	0	0	0	7		0	0	0	0	0			0
Jefferson	8	5	7	1	0	0	0	0	21		0	0	0	0	0			1
Johnson	1	1	4	6	0	0	0	0	12	15	0	0	0	0	0			0
Lafayette	4	11	37	14	0	0	0	0	66	5	0	2	2	0	4			2
Lee	1	0	1	0	0	0	0	0	2		0	0	0	0	0			0
Lincoln	0	1	5	0	2	0	0	0	8		1	0	0	1	2			0
Little River	9	9	12	3	0	0	0	0	33		1	1	0	0	2			2
Logan	1	5	6	2	3	0	0	0	17	1[1]	0	0	0	0	0			0
Lonoke	0	1	7	0	0	0	0	0	8		0	0	0	0	0			1
Madison	0	2	2	0	0	0	0	0	4		0	0	0	0	0			0
Miller	2	20	31	24	3	0	0	0	80	6	1	4	8	2	15	3	6	6
Mississippi	1	4	0	0	0	0	0	0	5		0	0	0	0	0			0
Montgomery	1	0	0	0	0	0	0	0	1		0	0	0	0	0			0
Nevada	5	38	25	7	2	0	1	0	78	142	0	0	0	0	0			2
Ouachita	1	32	125	23	1	0	0	0	182	1,408	0	0	0	0	0	2	1	2
Perry	0	1	0	0	0	0	0	0	1		0	0	0	0	0			0
Phillips	4	4	1	0	0	0	0	0	9		0	0	0	0	0			0
Pike	3	4	3	0	0	0	0	0	10		0	0	0	0	0			0
Poinsett	1	1	5	3	0	0	0	0	10		0	0	0	0	0			0
Polk	0	1	0	0	0	0	0	0	1		0	0	0	0	0			0
Pope	0	7	3	4	3	0	0	0	17	2[1]	0	0	0	0	0			0
Prairie	2	1	6	0	0	0	0	0	9		0	0	0	0	0			0
Pulaski	4	4	1	0	0	0	0	0	9		0	0	0	0	0			0
Randolph	1	0	0	0	0	0	0	0	1		0	0	0	0	0			0
Saline	1	0	2	3	0	0	0	0	6		0	0	0	0	0			0

[1] Not listed in Table 1.

TABLE 2.—(*Continued*)

County	Completed Prior to Jan. 1, 1934: Dry and/or Near-dry Holes: Total Depths, Ft. 500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	Total	Productive Wells (For Details, See Table 1)	Completed during 1933: Dry and/or Near-dry Holes: Total Depths, Ft. 1000–2000	2000–3000	3000–4000	4000–5000	Total	Productive Wells (For Details, See Table 1)	Drilling or Incomplete at End of 1933: Within Fields	Exploratory
Scott	0	7	7	0	0	0	0	0	14	3	0	0	0	0	0			0
Searcy	0	2	1	0	0	0	0	0	3		0	0	0	0	0			0
Sebastian	4	6	13	3	1	0	0	0	27	84	0	0	0	0	0			0
Sevier	4	2	2	0	0	0	0	0	8		1	0	0	0	1			0
St. Francis	1	0	5	3	0	0	0	0	9		0	0	0	0	0			0
Union	10	28	314	200	7	0	0	1	560[2]	4,264	3	2	6	0	11	1	2	5
Van Buren	0	2	1	1	0	0	0	0	4		0	0	0	0	0			0
Washington	2	7	2	0	0	0	0	0	11		0	0	0	0	0			0
White	1	5	2	2	0	0	0	0	10		0	0	0	0	0			0
Woodruff	1	4	1	0	0	0	0	0	6		1	0	0	0	1			0
Yell	1	5	6	2	0	1	0	0	15		0	0	0	0	0			0
Total	119	339	832	416	28	1	1	1	1,737	6,265	9	9	17	3	38	4	9	26

[2] Incomplete.

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Developments in the California Oil Industry during the Year 1933

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(New York Meeting, February, 1934)

Although the year 1933 was a period of uncertainty, considerable new development was initiated, with a high percentage of favorable results, for owing to financial conditions only projects of merit were proposed and developed.

Unfavorable marketing conditions caused severe financial losses to refinery and sales departments of nearly all companies during the first half of the year. In anticipation of stabilized Government control, earnings were generally favorable during the third quarter but failure of the Government to take legal action against violators of the proration orders, and lack of agreement on a definite plan of curtailment, resulted in considerable overproduction and demoralization of the market structure during most of the final quarter. However, toward the close of the year Government action against violators of the Oil Code had a tendency to decrease overproduction materially and give the market a firmer tone. As a whole, the price structure of crude oil was maintained at a high level during the year; in fact, at a much higher level than the price of refinery products warranted.

At no time during the year was production within 10,000 bbl. daily of the state allotment, overproduction of crude reaching a peak of 70,000 bbl. on Sept. 7, average daily average for the year being about 27,000 barrels.

Numerous plans for equitable curtailment were prepared and tested during the year, none of which fully solved the many and intricate problems faced by operators who were in most cases willing to curtail if they could feel that cooperation was being practiced by their neighbors.

Outstanding events in California oildom during the period under discussion may be classified under the following headings:

1. New discoveries.
    (a) New development in proven areas.
    (b) Deeper zones in settled pools.
2. Unproductive wildcat operations.
3. Whipstocking practice and procedure.
4. Progress of unit and orderly plans of development.

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5. Geophysical prospecting.
6. Improvements in drilling and producing equipment and practice.
7. Decline and/or increase of
    (*a*) Oil reserves.
    (*b*) Gas reserves.
8. Production and consumption of California motor fuel (gasoline, engine distillate and natural gasoline), also domestic shipments and exports.

New Discoveries

New Development in Proven Areas

Huntington Beach.—The Townsite area of this field experienced a major drilling boom after the Vicaroo Oil Co. completed its No. 1 well in January for a large producer from a depth of 4500 ft. The drilling of this well was precipitated by the discovery that holes could be deflected into an undrilled portion of the Townsite pool under state tide lands. During the year numerous wells have been completed at depths ranging from 4500 to 5000 ft. for as high as 5000 bbl. per day of clean oil. In certain instances wells were completed unexpectedly as gassers, with initial production of about 40,000,000 cu. ft. per day. However, owing to the gas law, which prohibits gas wastage, these wells were either shut in or redrilled and the gas zone was cased off.

Kettleman Hills—North Dome.—A new depth record was established by the drilling by the North Kettleman Oil & Gas Co. of Lillis-Welch No. 1 to 10,944 ft. with standard rotary equipment. This well was never successfully completed as a producer, although it showed some oil and gas when tested for shutoff below 9638 ft. The well has experienced much mechanical difficulty and is in the process of redrilling. The showings obtained from this well, during shut-off test, came from Eocene formations, which indicates that deeper drilling in the main portion of the North dome will result in productive completions below the Temblor horizon.

Development in Kettleman Hills North dome continued at a slow rate during the year, drilling being concentrated at the north end of the field. Edge-water conditions were encountered in several edge wells and clean production was secured after considerable difficulty. New wells being drilled on the edge are successfully eliminating edge-water sands from productive formations by using formation testers at frequent intervals as drilling proceeds.

A well drilled by Kenda in a high structural position on the north plunge isolated and proved productive an additional 600 ft. of formation below the usual penetration of 1450 ft. This well bottomed in the Kreyenhagen (Oligocene) shale and indications are that at least 2000 ft. of formations will be productive on the highest parts of the structure.

Although development and production has been mainly confined to the north end of this structure, with the view of holding the southern

portion as a reserve, nevertheless results obtained from producing a few wells to the south indicate that the pressure has decreased over the entire structure. The increasing gas-oil ratios of wells in this field also indicate that the drainage radius of producing wells is still increasing. Knowledge obtained from development in this field throughout the year tended to reduce the estimate of reserves set up in previous years.

Mountain View.—This field assumed an aspect of greater importance when Dana Hogan finished his Wharton No. 1 well as a commercial producer in May, 1933. The existence of an oil field at Mountain View was more or less generally recognized in view of exploration work conducted by the Shell Oil Co. in that area some two or three years ago. The Shell Company, after making a discovery, ceased drilling operations as a conservation measure. Recently, the Mohawk Oil Co. completed its Glendennin No. 1 well from the Chanac formation for 1500 bbl. per day of 28.5° gravity clean oil, which proves that this field will be productive both in the Kern River and Miocene horizons. The areal extent of the field is as yet unknown but should be comparable to Fruitvale, which embraces 1220 proved acres. Drilling and producing in this field is proceeding under a plan of orderly development, approved by the Secretary of the Interior.

North Belridge.—The Ohio Oil Co. was instrumental in proving that the very prolific zone penetrated by the Belridge No. 64 well on top of the structure between the depths of 7876 to 8000 ft. extended at least ½ mile down the flanks on the east side of the field when its Bloemer No. 1 well flowed 750 bbl. per day of 33° gravity clean oil from between the depths of 8415 to 8525 ft. in March, 1933. The completion of this edge well indicates that the Wagon Wheel zone will be productive over an area of approximately 3700 acres. Like Kettleman Hills, the zone has a gas cap on top of the structure but large completions of high-gravity oil with a low gas-oil ratio will be possible on the flanks of the structure. It is expected by agreement of all operators that a unit plan of development will be formulated and placed in operation.

Richfield.—A limited drilling boom was instigated in the eastern part of this field during midyear after Otis Hoyt completed his No. 15 well from between the depths of 3724 to 3832 ft. for 600 bbl. per day of 29.5° gravity clean oil accompanied by 1,000,000 cu. ft. gas. This production was obtained by isolating a small body of productive sand on the edge of the structure. Rate of decline has been rapid and some wells have failed to find the productive zone even though drilled but a few locations from the discovery well.

Rincon.—An attempt to extend the Rincon field about 2000 ft. farther into the ocean was partly successful. Indian Petroleum Corporation succeeded in completing its tideland well as a small producer from around 3450 ft. The steel island on which this well was drilled was an isolated

structure about 2800 ft. from the mainland and was one of the interesting features of the operation. Recently this well was deepened to 4125 ft. and no showings were encountered below the zone at 3450 ft., to which depth it was subsequently plugged.

Deeper Zones in Settled Pools

Montebello.—After several unsuccessful attempts by the Standard Oil Co. and the St. Helens Petroleum Co. to find production in the deeper horizons in the western portion of this field, the Universal Oil Co. drilled a deep test in the extreme east end of the Montebello anticline, to a depth of 7010 ft., and completed it as a commercial producer in August for an initial of about 700 bbl. per day of 36° gravity oil together with 300,000 cu. ft. gas. Production is being derived from the middle Puente sandstone, found in this area about 1400 ft. below the top of the Miocene. Undoubtedly this productive horizon underlies other fields in the Los Angeles Basin, especially Santa Fe Springs, which will serve as an impetus to deeper drilling in many of the older fields. The rate of development will be slow because a few operators control the acreage in this field. An orderly plan of development is being considered for submission to the Secretary of the Interior.

Mount Poso.—Deeper drilling in this field proved the productivity of a deeper zone, which has been designated as the Lower Vedder. The Shell Oil Co. drilled its Vedder No. 6 well to 1825 ft. and, with the Upper and Lower Vedder formations open, completed the well for 740 bbl. per day of 16.4° gravity clean oil. Wells formerly produced but 50 to 75 ft. of what is known as the Upper Vedder zone. Practically a dozen wells have been completed in the Lower Vedder during the past year. The productive area of the Lower Vedder is considered to be very limited.

San Miguelito.—Penetrating to a depth of 7926 ft., the Continental Oil Co. Grubb No. 2 well added approximately 700 ft. of productive measures to those previously uncovered in this field. The well was completed from between the depths of 7298 to 7926 ft. for 1200 bbl. per day of 30° gravity oil. Development of this pool is progressing very slowly, as the Continental Oil Co. controls the entire productive acreage of this field.

Unproductive Wildcat Operations.—The Standard Oil Co. drilled a well on the Santa Rosa Island, located off the coast of Santa Barbara, to a depth of 6287 ft., without obtaining any showings, and this well was abandoned in February. A large expenditure was necessary in order to carry out this test and the absence of showings greatly discouraged those who were instrumental in having the area tested.

The San Miguel anticline in the Paso Robles district was tested to a depth of 5971 ft. by the Shell Oil Co., with negative results. The well suspended drilling in barren sands of Vaqueros age and was subsequently

abandoned. The Shell Oil Co. had extensive holdings in this area, all of which will be quitclaimed. All tests drilled in the Salinas Valley to date have proved unproductive.

The Superior Oil Co. has abandoned its Mantes No. 1 well, on the southeasterly plunge of the Jacalitos dome in Fresno County. This well was drilled to a depth of 7838 ft. and bottomed in Kreyenhagen hard brown shale. During its drilling it penetrated the Jacalitos-Etchegoin, and Miocene brown shale and Temblor formations but encountered no showings. The barrenness of the formations penetrated, coupled with past failures drilled on the Jacalitos dome, indicates that this structure is probably not oil-bearing.

Whipstocking or Directional Drifting.—These methods of drilling wells received a great impetus during 1933, more so than in any period of oil-land development. Since the conceptions of these methods, it was evident that they were both useful and susceptible of abuse. Lately these practices are reported to have been greatly abused, for in numerous instances wells have been intentionally directed and drilled under neighboring productive leases when it was discovered that commercial production could not be obtained by drilling a straight hole. Also, old abandoned wells, which had gone to water or become nonproductive, were opened up and redrilled from near the surface, in order that a favorable amount of drift could be obtained to place the bottom of the well in productive territory.

The State of California has instituted a suit against Huntington Beach Townsite operators for directing wells, with surface locations on the mainland, under other company leases and the ocean bed to tap state tideland oil reserves. It is reported that wells have deflected at least 1800 ft. distant from their surface locations at a depth of 5000 feet.

Progress in Unit and Orderly Plans of Development.—Plans for unit and orderly plans of development were further formulated and discussed during the present year, with the result that three fields have been placed under orderly plan of development operations and one under unit plan of development operations. The Kettleman Hills Middle dome unit plan was approved and became effective Oct. 6. Fields that have submitted orderly plans of development that have been approved are San Miguelito, Premier and Mountain View. The following fields or pools have yet to submit orderly development plans: Belridge (Wagon Wheel), Dominion, Alferitz, Agey, Edison, Capitan (Vaqueros), Elwood (Sespe), Huasna, Inglewood (Deep), Montebello (Cruz) and Chino.

Geophysical Prospecting.—A considerable amount of prospecting of this nature was undertaken by various California operators throughout the year. The major portion of this work was accomplished with seismograph reflection instruments by the Geo-Physical Research Corporation and the Geo-Physical Service, Inc. Large tracts of land in the San

Joaquin Valley were subjected to exhaustive tests with the result that many blocks of acreage were leased, and during the year two tests were located, which are being drilled, on prospective structures. It is felt that this method of prospecting will receive added impetus in this state, if and when it proves its worthiness.

Improvements in Drilling and Producing Equipment and Practice.—During the past year drilling methods and equipment have advanced a considerable degree, as evidenced by the following discussion.

The most noteworthy development has been the use of directed drilling practices, which has attracted a great amount of interest. There has been a considerable improvement in the art of preventing drift and also causing drift of drill holes.

The practice of running single-shot surveying instruments during the drilling of wells, to determine both the inclination and direction of drift, has become general. This is especially true in town-lot fields and those where the productivity of the sands shows considerable lateral variation. For wide drift, the rotary table is usually tilted and the kelly inclined on spudding. Variations in direction or inclination in the hole are brought about through the use of whipstocks, usually of the removable type, also by controlling the flexing of the drill pipe and by choice of bits and the use of reamers. Holding the course of the hole is accomplished by using long, heavy, stiff collars centered by reamers and by controlling the weight on the bit.

Experiments in drilling point to the desirability of light drilling weights and considerably increased rotating speed. Gages indicating table speed and drill-stem torque are available and in use where desired along with the familiar weight indicators and mud-weighing devices.

Great progress has been made in methods and devices for excluding intermediate water in oil zones. Intermediate waters of low head are being rather successfully excluded by a simple cementing under pressure method through perforations at the entry point. Multiple cement jobs, made by cementing behind blank sections in the perforated string at the time it is run, show great promise. This type of operation should make available considerable quantities of oil not now commercially available in fields where water encroachment is serious. It should also ultimately lead to much more economical casing programs than those required by former and present practice. By cementing through perforations in the oil string at points where the shutting off of upper waters is now required by a separate string of casing, extra casing could be eliminated and the hole could be started with a smaller diameter.

Coring has been greatly improved by the use of hard facing on core bits. Core heads now hold their gage so well that it has become practicable to increase the diameter of the core head and barrel. Cutting a thinner annular space has resulted in faster coring and the increased

size of the core has resulted in improved recovery, which is especially noticeable in the smaller sizes of core heads.

Formation testers are being more generally used, not only for testing new formations without the necessity of setting casing but also for making water shut-off tests. Many companies have standardized on them for both purposes.

Electrical coring is becoming more prominent and is proving to be especially valuable in the development of new fields. Resistivity and porosity data determined by this means are valuable supplements to coring data.

Flush joint casing, with special inserted thread and collared pipe, with thin couplings of increased tensile strength, are making possible a saving in casing by enabling operators to start with smaller holes and run long strings of casing with small clearances between pipe and hole.

New types of equipment, which have gained considerable usage, include hydromatic brakes on draw works, vertical steam drilling engine, gun perforator for perforating casing in the hole by discharging a series of electrically detonated shells, using hardened steel bullets and an electric device for detecting point of entry of water in a flowing well without killing the well. Portable, gas-engine-driven drilling machines with 125 to 150-hp. engines, are being adopted for use in repairing wells, cleaning out and for short redrilling jobs, where depth is not too great. Results, so far, indicate that great economy is resulting from their use, in such cases, and that this type of machine will be more widely adopted.

In the producing field, perhaps the most notable trend is toward the use of multicylinder gas engines for pumping wells. Low first cost and operating economy favor this type of power engines over steam engines, electric motors or single-cylinder horizontal gas engines. Under curtailment the somewhat greater down time under gas-engine power is not an important objection.

In spite of the common impression to the contrary, reconditioned automobile engines are giving satisfactory service, where the application has been carefully planned and the engines sufficiently underloaded. Engines designed for this service are coming into the market now, which are fundamentally of the tractor type, modified and adapted for stationary use. Some of the improvements include higher compression heads, improved gas-air carburetors, forced lubrication, solid-cast combined crankcase and base and improvements to increase accessibility.

In the case of electric power, some research is being done in the improvement of power factors, making possible lower power rates.

Geared or chain-driven pumping units are being adopted by major companies for pumping deep wells, not already equipped with some other pumping means. Anticipated difficulties in pumping deep wells with low fluid levels are proving to be overestimated. Results in pump-

TABLE 1.—*Oil and Gas Production in California*

Line Number	Field, *County*	Year Discovered	Age,[1] Years to End of 1933	Area Proved, Acres	
				Oil and Gas[a]	Gas
	Los Angeles Basin Fields				
1	Alamitos Hgts., *Los Angeles*	1927	7	110	
2	Brea Olinda, *Orange*	1880	47	1,410	
3	Dominguez, *Los Angeles*	1923	10	665	
4	East Coyote, *Orange*	1911	22	[2]	
5	West Coyote, *Orange*	1906	22	1,825[2]	
6	Huntington Beach, *Orange*	1920	14	1,845	
7	Inglewood, *Los Angeles*	1924	10	865	
8	Lawndale, *Los Angeles*	1928	5	13	
9	Long Beach, *Los Angeles*	1921	13	1,305	
10	Los Angeles—Salt Lake, *L. A.*	1890	40	990	
11	Montebello, *Los Angeles*	1917	17	1,078	
12	Playa Del Rey, *Los Angeles*	1929	4	320	
13	Potrero, *Los Angeles*	1927	6	113	
14	Richfield, *Orange*	1919	15	1,278	
15	Rosecrans, *Los Angeles*	1924	10	310	
16	Santa Fe Springs, *Los Angeles*	1919	13	1,138	
17	Seal Beach, *Los Angeles*	1926	8	330	
18	Torrance, *Los Angeles*	1922	12	3,835	
19	Whittier, *Los Angeles*	1901	22	575	
20	Total Los Angeles Basin			18,005	
	San Joaquin Valley Fields				
21	Belridge, North and South, *Kern*	1911	21	2,415	
22	Coalinga, *Fresno*	1887	38	14,669	
23	Coffee Canyon, *Kern*	1928	0.7	100	
24	Elk Hills, *Kern*	1919	15	9,850	
25	Fruitvale, *Kern*	1928	6	1,220	
26	Kern Front, *Kern*	1912	7	3,050	
27	Kern River, *Kern*	1899	34	6,973	
28	Kettleman Hills North Dome, *Kings, Fresno*	1928	5.2	17,610	
29	Kettleman Middle Dome, *Kings*	1931	0.8	1,280	
30	Lost Hills, *Kern*	1910	22	2,310	
31	McKittrick, *Kern*	1887	36	1,710	
32	Midway Maricopa, *Kern*	1900	34	48,600	
33	Mountain View, *Kern*	1933	0.6	40	
34	Mount Poso, *Kern*	1926	7	1,360	
35	Round Mountain, *Kern*	1927	0.7	901	
36	Wheeler Ridge, *Kern*	1922	11	320	
37	Buttonwillow, *Kern*	1926	4		750
38	Tulare Lake, *Kern*	1929			1,900
39	Total San Joaquin Valley District			112,408	2,650
	Coastal District				
40	Capitan, *Santa Barbara*	1929	4	120	
41	Elwood, *Santa Barbara*	1928	5	400	
42	Rincon, *Ventura*	1927	6	350	
43	San Miguelito, *Ventura*	1931	2	200	
44	Santa Barbara, *Santa Barbara*	1929	4	50	
45	Santa Maria, *Santa Barbara, San Luis Obispo*	[3]	[3]	10,687	
46	Summerland, *Santa Barbara*	1892	41	120	
47	Ventura Ave, *Ventura*	1916	17	1,760	
48	Ventura Newhall *Ventura, Los Angeles*	[4]	[4]	4,685	
49	Watsonville, *San Mateo-Colusa, Sonoma-Humboldt, Santa Clara*	1886		100	
50	Goleta, *Santa Barbara*	*y*	[5]		
51	Moore Ranch, *Santa Barbara*	1929	4		180
52	Total—Coastal District			18,472	180
53	Total—California			148,885	2,830

[a] Footnotes to column headings indicated by letters and explanation of symbols are on page 175.
[1] The time elapsed since date of first production.
[2] West Coyote and East Coyote combined.
[3] Fields in Santa Maria Area: Arroyo Grande, *San Luis Obispo;* 1910; 270 acres, productive zone, 800; Mio; syncline. Casmalia, *Santa Barbara;* 1910; 1130 acres; productive zone, 3500; Mio; anticline. Cat Canyon, *Santa Barbara;* 1911; 1187 acres; productive zone, 2800–3500; Pli; anticline. Gato Ridge, *Santa Barbara;* 1931; 700 acres; productive zone, 1750; Mio; anticline. Huasana, *San Luis Obispo;* 1929; Mio; syncline. Lompoc, *Santa Barbara;* 1904; 2780 acres; productive zone, 2200–4100; Mio; anticline fault. Santa Maria, *Santa Barbara;* 1901; 4620 acres; productive zone, 1200–1800, 2400–2600, 3300–4500; Mio; anticline fault.
[4] Fields in Ventura Newhall Area: Bardsdale, *Ventura;* 1894; 510 acres. Oli; anticline. Conejo, *Ventura;* 1898; 95a cres; Pli; seepage accumulation. Newhall, *Los Angeles, Ventura;* 1875; 346 acres. Mio; anticline. Ojai, *Ventura;* 1885; 430 acres; Mio; fault accumulation. Piru, *Ventura;* 1882; 742 acres; Mio; anticline. Santa Paula, *Ventura;* 1875; 465 acres; Pli; monocline-fault. Shiells Canyon, *Ventura;* 1911; 260 acres; productive zone 100–3000; Oli; anticline. South Mt., *Ventura;* 1916; 720 acres, productive zone 1400–4200; Oli; dome. Sulphur Mt., *Ventura;* 1927; Mio; dome. Timber Canyon, *Ventura;* 1890; Pli; monocline-fault. Tip Top, *Ventura;* 1918; Pli; faulted anticline. Torrey Canyon, *Ventura;* 1896; Mio; anticline.
[5] Field abandoned.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl. To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Average Oil Production, Bbl. Per Acre to End of 1933[5]	Per Well Daily during Nov., 1933	Total Gas Production, Millions Cu. Ft. To End of 1933	During 1932	During 1933	Maximum Daily during 1933
1	[6]	962,020	833,380	2,229	[6]	38.4	[6]	[6]	[6]	[6]
2	146,841,489	3,018,125	2,964,674	9,809	104,124	33.5	65,714[10]	3,894	3,478	10.700
3	63,188,447	6,823,579	6,626,605	13,221	95,024	189	94,667	9,892	10,940	34.200
4	[2]	584,240	579,853	2,509	[2]	30.9	[2]	[2]	2.4	0.040
5	135,383,461[2]	3,132,227	3,118,519	8,722	74,183[2]	322	31,536[2,10]	2,096[2]	2,445	8.330
6	202,556,445	8,016,001	13,091,926	56,207	109,787	118	176,238[10]	4,529	12,333	69.600
7	88,679,063	4,869,335	4,059,973	8,131	102,519	40.5	70,620	2,997	1,077	5.920
8	311,480	110,350	79,460	145	23,960	18.1	84[e]		185	0.600
9	502,178,122	27,435,553	24,798,242	58,075	384,811	56.2	722,330[10]	32,490	27,314	87.500
10	64,267,997	394,124	313,810	899	64,917	5.2	y	y	y	y
11	93,056,913	2,162,530	1,933,121	6,214	86,323	34.6	20,699[10]	367	319	1.320
12	24,474,286	5,910,926	4,059,240	8,722	76,482	47.6	23,365	6,285	4,887	15.100
13	1,765,225	252,609	141,791	374	15,621	34	1,846	164	31	0.324
14	71,791,339	2,263,699	2,467,913	8,356	56,175	38.7	65,343[10]	2,701	3,060	11.500
15	28,337,241	1,125,624	1,080,247	3,104	91,410	40.8	45,784	1,870	2,071	6.225
16	370,897,210	22,538,036	18,271,807	38,140	325,920	74.1	592,569[10]	27,462	18,659	64.500
17	65,290,013[6]	3,560,469	3,158,521	7,075	148,386[6]	124	73,286[6]	2,173[6]	3,294[6]	14.800[6]
18	75,188,443	2,281,274	2,362,719	7,289	19,606	15.2	55,080[10]	1,433	1,343	3.920
19	15,873,130	399,540	404,128	1,051	27,605	6.6	366[10]	77	23	0.216
20	1,950,080,304	95,840,261	90,346,029	240,272	108,308		2,040,292[10]	98,430	91,461.4	334.795
21	70,887,784[7]	3,032,876	2,867,079	7,306	15,003[7]	69.5	28,427[7,10]	8,544[7]	5,806[7]	19.900[7]
22	326,701,077	3,649,578	4,423,512	17,098	22,272	21.8	971[10]	279	266	0.975
23	[8]	[8]	[8]	1,659	[8]	66.3				
24	128,617,928	4,537,461	4,487,978	10,833	13,058	56.5	81,110[10]	1,986	1,390	4.260
25	5,772,593	1,600,801	1,672,805	4,342	4,732	67.9				
26	[9]	2,521,556	2,340,103	7,116	[9]	25.1				
27	292,532,832[9]	865,706	869,907	2,311	29,186[9]	2.9				
28	69,326,779	21,949,072	21,472,041	48,418	3,937	836	633,289	98,967	104,426	363.000
29	162,516	10,537	151,979	507	127	507	3,270		3,270	19.700
30	[7]	297,108	338,794	1,358	[7]	10.4	[7]	[7]	[7]	[7]
31	82,462,421	651,792	651,361	1,874	48,224	11.9				
32	744,858,938	17,929,036	17,541,812	51,376	15,326	24.6	262,315[10]	18,335	16,804	47.500
33	233,341		233,341	957	5,834	191	80		80	0.985
34	14,772,273	2,907,839	3,050,826	8,519	10,862	72.7	y	11	2.4	y
35	3,764,874[8]	928,814[8]	1,118,913[8]	1,854	3,761[8]	169				
36	2,911,038	187,299	168,918	449	9,097	13.2				
37							4,065	80	18.6	0.206
38										
39	1,743,004,394	61,069,475	61,389,369	165,977	15,506		1,013,527[10]	128,202	132,063	456.526
40	108,986	3,092	24,621	259	908	37.1				
41	45,853,988	5,441,626	4,918,488	13,505	114,635	288	41,428	4,852	2,478	7.978
42	5,302,927	628,179	680,471	1,473	15,151	52.6	5,579	557	522	1.680
43	667,055	252,247	390,559	1,073	3,335	357				
44	540,451	156,446	249,426	611	10,809	47				
45	129,774,816	1,080,723	1,254,818	5,297	12,143	28.6	27,091[10]	1,606	1,612	4.980
46	3,076,441	39,386	31,434	77	25,637	1.9				
47	142,361,394	12,332,853	12,576,208	31,091	80,887	171	522,801[10]	40,318	38,963	124.000
48	51,097,172	1,259,755	1,199,997	3,843	10,906	8.2	y	2,259	1,868	y
49	67,618	22,824	21,999	60	676	10				
50	y	0	0	[5]	y					
51							5,034	941	1,505	5.350
52	378,850,848	21,217,131	21,348,021	58,189	20,509		601,933[10]	50,533	46,948	143.988
53	4,071,935,546	178,126,867	173,083,419	464,438	27,350		3,655,752[10]	277,165	270,472.4	935.309

[6] Seal Beach and Alamitos Heights combined.
[7] Lost Hills and Belridge combined.
[8] Round Mountain and Coffee Canyon combined.
[9] Kern Front and Kern River combined.
[10] Subsequent to 1922.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933		
	Completed to End of 1933	During 1933		At End of 1933				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil and Gas	Producing Gas Only	Total Producing			Flowing	Pumping	Gas-lift
1	[6]			2	58		58	5,700	4,610		58	
2	620			118	292		292	2,821	[11]		292	
3	140	15	1	35	70		70	4,410	3,750	32		38
4	[2]	[2]		8	81		81	3,615	[12]		81	
5	372[2]	6[2]	1	89	27		27	4,191	[13]	10	15	2
6	1,067	51	20	121	474		474	[25]	1,900	51	397	26
7	278		1	47	201		201	2,410	1,100		201	
8	7	1	2		8		8	5,850	5,750		8	
9	1,859	50	32	100	1,035		1,035	5,575	[14]	38	833	164
10	1,617		63	7	173		173	1,083	[15]		173	
11	237	1		13	179		179	3,219	1,800[16]	1	178	
12	240	4	36	6	183		183	5,086	[17]		183	
13	33		5	1	11		11	5,730	[18]		11	
14	399	4	3	66	216		216	4,149	2,200[19]		216	
15	204		3	10	76		76	5,150	3,700[20]		76	
16	1,004	4	16	132	515		515	5,480	3,300[21]	4	420	91
17	231[6]		9	25	57		57	5,396	[22]	8	37	12
18	880	2	6	8	479		479	3,682	[23]		479	
19	290		1	10	162		162	2,082	[24]		162	
20	9,478	138	199	798	4,297		4,297			144	3,820	333
21	816[7]	4		197	105		105	[26]		11	94	
22	1,900		8	605	783		783	[27]			783	
23	[8]			1	25		25	1,649			25	
24	368			105	192		192	3,026			192	
25	73	10	2	7	64		64	3,956			64	
26	[9]			41	283		283	2,195			283	
27	3,143[9]		8	1,410	777		777	767			777	
28	69	22		6	58		58	8,222	[28]		54	4
29	1				1		1	7,880		1		
30	[7]			253	130		130	[29]			130	
31	546	0	1	161	157		157	1,177			157	
32	4,295	9	23	1,439	2,085		2,085	[30]			2,085	
33	9	7	1		5		5	5,900		5		
34	153	16	9	23	117		117	1,703			117	
35	65[8]	6	1	26	11		11	1,919			11	
36	38				34		34	2,716			34	
37	20	4	1	20								
38	3		2	3								
39	11,499	78	56	4,297	4,827		4,827			17	4,806	4
40	11			5	7		7	1,450	[31]		7	
41	75	5	1	10	47		47	3,368	[32]	2	26	19
42	45	1		9	28		28	3,635	[33]		16	12
43	3	1	1		3		3	7,597	6,470	2	1	
44	22	7	1		13		13	2,124	2,036		13	
45	517		5	234	185		185	2,874[3]	[3]		185	
46	322		1		40		40	400	y		40	
47	328	8	2	73	187		187	6,451	[34]	148	3	36
48	1,275	9	30	151	468		468	[4]	[4]		468	
49	27				6		6	1,100	y		6	
50	y	0	0		0	0	0					
51	4	1	1			4	4	4,490	4,139	4		
52	2,629	32	42	482	984	4	988			156	765	67
53	23,606	248	297	5,577	10,108	8	10,112			317	9,391	404

[11] 1200, 2100, 2600, 3200, bottom 3600. [12] 2450, 2900, 4000.
[13] 2800, 3300, 4200. [14] 2300, 2950, 3300, 5000.
[15] Los Angeles, Salt Lake, 650, 1550. 2450, 3650; Los Angeles City field, 475, bottom 1500.
[16] 1750, 2450, 3550. [17] 3500, 5500. [18] 3700, 5420, 6400. [19] 1900, 2850, 3700.
[20] 3700, 3900, 4120, 4540, 4650, 4740, 4820, 4900.
[21] 2000, 3470, 3600, 4050, 4950, 5500, 6240, 6740, 7205.
[22] 4300, 4550, 4870, 5920, 7150. [23] 2700, 3100, 3550. [24] 250, bottom 3500. [25] New field, 3994; old field, 4042.
[26] Shallow zone, 915; deep zone, 5461. [27] East Coalinga, 2089; West Coalinga, 1614.
[28] Gas zone, 6070; oil zone, 6675. [29] Shallow, Lost Hills, 688; deep zone, 1690.
[30] Shallow zone, Midway, 1351; deep zone, Midway, 2749; Buena Vista Hills, 3289.
[31] 1265, 2730. [32] 3164, 4325. [33] 2500, 2900. [34] 5100, 8600.

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F. Maximum	Minimum	Weighted Average	Base[f]	Character of Gas, Approx. Average during 1933: Gal. Gas per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Net Thickness, Average, Ft.	Structure[f]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.	Estimated Oil Reserves 1-1-34 Thousands Bbl.
1	30	23	26	A	1.4	Pico, Puente	Pli, Mio	SH	2,300	AF			9,054	[6]
2	31	16	26	A	2.4	Puente	Mio	SH	2,500	MF, AF	41		8,201	48,700
3	43	26	27	A	2.0	Pico	Pli	SH	2,000	A	29		8,922	80,000
4	28	18	21	A		Pico, Puente	Pli, Mio	SH	800	A	[2]		9,084	[2]
5	28	18	21	A	1.8	Pico, Puente	Pli, Mio	SH	2,000	A	15[2]		8,144	64,300[2]
6	27	11	23	A	1.4	Pico, Puente	Pli, Mio	SH	1,500	MF	110		9,054	75,000
7	29	13	20	A	1.2	Pico	Pli	SH	1,200	AF	15		6,466	93,000
8	31	22	31	A	2.1	Puente	Mio	SH	700	ML	59			300
9	31	17	25	A	2.8	Pico, Puente	Pli, Mio	SH	5,600	AF	319		9,280	158,000
10	22	12	15	A		Pico, Puente	Pli, Mio	SH	2,000	MF, AF	101			9,850
11	30	17	23	A	0.9	Pico, Puente	Pli, Mio	SH	2,500	AF	29		7,010	40,000
12	26	20	24	A	2.5	Pico, Puente	Pli, Mio		1,200	A	31		6,778	21,900
13	45	34	38	A		Pico	Pli	SH	400	AF	20			1,420
14	30	14	21	A	1.2	Pico, Puente	Pli, Mio	SH	1,500	A	84		5,933	19,000
15	41	30	36	A	2.6	Pico	Pli	SH	1,200	A	88		7,591	5,500
16	36	27	32	A	1.7	Pico, Puente	Pli, Mio	SH	3,200	A	103		9,610	65,000
17	30	23	26	A	1.4	Pico, Puente	Pli, Mio	SH	2,000	AF	44		7,969	34,000
18	27	11	19	A	2.4	Pico, Puente	Pli, Mio	SH	400	A	25		5,938	14,000
19	24	13	20	A		Pico	Pli	SH	3,000	MF	25		5,040	1,800
20														731,770
21	41	13		A	0.8	Etchegoin, Temblor, Wagon Wheel	Pli, Mio, Eoc	SH	800	A	52[7]	[35]	8,525	259,000
22	34	13		A		Temblor, Santa Margarita, Jacalitos	Mio, Cre U	SH	420	MUP, A	90		4,759	55,000
23				A		Vaqueros	Mio	SH		FM				
24	38	15		A	1.8	Etchegoin	Pli	SH	300	A	21		8,404	222,700
25	22	15		A		Kern River, Etchegoin	Pli	SH	500	MF	10		7,725	24,200
26	16	12		A		Kern River, Etchegoin	Pli, Pli	SH	275	MF			4,664	34,200
27	16	12		A		Kern River	Pli	SH	450	MF	32		5,135	14,000
28	64	33		A	1.2	Temblor	Mio	SH	1,100	A	11		10,944	1,439,000
29				A	0.8	Temblor	Mio	SH	300	A	1		9,332	40,000
30	27	14		A		Etchegoin	Pli	SH	300	A	[7]		5,891	[7]
31	15	11		A		Etchegoin	Pli, Mio	SH	200	AF	17		6,664	9,200
32	28	11		A	1.7	Etchegoin, Santa Margarita, Maricopa	Pli, Mio, Mio	SH	2,000	MC	153		9,753	192,000
33	21	21		A		Kern River, Santa Margarita	Pli, Mio	SH	260	MF	0		8,419	10,000
34	16	15		A		Vaqueros	Mio	SH	280	MF	38		3,130	48,500
35	17	16		A		Vaqueros	Mio	SH	480	MF	16		3,763	40,000
36	23	22		A		Maricopa	Mio	SH	2,400	A	3		7,154	615
37						Tulare, Etchegoin	Pli	SS	1,600	D	4		4,946	
38						Tulare	Mio	S	150	H	0		4,310	
39														2,388,415
40	43	19		A		Vaqueros, Sespe	Mio, Oli			A	7		4,071	12,000
41	37	30		A	1.5	Vaqueros, Sespe	Mio, Oli			AF	21		4,850	58,600
42	29	25		A		Pico	Pli			AF	12		7,449	5,700
43	28	22		A		Pico	Pli			AF	0		10,030	24,800
44	19	19		A		Vaqueros	Mio			MF	32		3,630	700
45	25	10		A	2.4	[3]					52		[36]	49,600
46	19	12		A		Fernando, Vaqueros	Pli, Mio			AF	121		5,041	385
47	30	24		A	1.0	Pico	Pli			D	26		9,710	154,000
48	36	15		P,A	1.0	[4]					429		y	9,500
49	17	10		A							30		y	375
50													y	
51						Vaqueros	Mio			AF	8		6,912	
52														315,660
53														3,435,845[37]

[35] Wagon Wheel. [36] Cat Canyon, 7199; Santa Maria, 5815.

[37] Including only reserves of pools and sands actually developed or proved; not including pools of which existence is known but which are still undrilled.

ing satisfactory volumes and reducing costs have been better than was expected.

Metal to metal pumps of increased accuracy of manufacture and of improved materials are demonstrating their desirability over older types. These are "pull out liner" pumps, mostly of the inverted type and metal tube pumps with ground cast plunger liners. Both types have decreased plunger friction, show good fluid delivery and are giving longer service.

Hydraulically operated pumps have continued to attract the attention of both oil operators and equipment designers and warrant the hope of a successful oil-well pump of this type in the near future.

TABLE 2.—*Summary of Drilling Operations in California*

(Figures in body of tabulation represent number of holes.)

County	Completed after Jan. 1, 1913 and Prior to Jan. 1, 1934												Completed during 1933											Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes											Productive Wells	Dry and/or Near-dry Holes												
	Total Depths, Ft.												Total Depths, Ft.												
	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000	More than 10,000	Total	(For Details, See Table 1)	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000	More than 10,000	Total	Within Fields	Exploratory
Almeda	5	0	1	0	0	0	0	0	0	0	6		0	0	0	0	0	0	0	0	0	0	0	0	0
Colusa	3	1	0	1	0	0	0	0	0	0	5		0	0	0	0	0	0	0	0	0	0	0	0	0
Contra Costa	7	0	0	0	0	0	0	0	0	0	7		0	0	0	0	0	0	0	0	0	0	0	0	0
Del Norte	1	0	0	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0
Fresno	27	12	9	17	10	4	0	0	0	1	80		2	1	0	2	3	1	0	0	0	1	10	20	7
Humboldt	19	1	0	0	0	0	0	0	0	0	20		0	0	0	0	0	0	0	0	0	0	0	0	0
Imperial	14	0	1	0	0	0	0	0	0	0	15		2	0	0	0	0	0	0	0	0	0	2	0	2
Kern	207	121	96	86	53	17	5	4	1	0	590		11	5	1	4	2	1	0	2	1	0	27	18	8
Kings	38	9	9	4	4	3	3	2	3	0	75		3	0	3	0	0	0	2	0	0	0	8	0	1
Los Angeles	159	79	122	176	173	75	19	8	0	0	811		4	1	3	4	3	2	2	0	0	0	19	27	14
Madera	0	3	1	2	0	0	0	0	0	0	6		0	1	0	0	0	0	0	0	0	0	1	0	0
Mendocino	0	1	0	1	1	1	0	0	0	0	4		0	0	0	0	0	0	0	0	0	0	0	0	0
Merced	6	0	2	1	0	0	0	0	0	0	9		0	0	0	0	0	0	0	0	0	0	0	0	0
Mono	2	0	0	0	0	0	0	0	0	0	2		0	0	0	0	0	0	0	0	0	0	0	0	0
Monterey	18	7	5	3	2	1	0	1	0	0	37		0	0	0	0	0	0	0	0	0	0	0	0	1
Napa	10	0	2	0	0	0	0	0	0	0	12		3	0	2	0	0	0	0	0	0	0	5	0	5
Orange	38	28	34	60	41	8	4	2	1	0	216		1	0	1	6	0	0	0	0	0	0	8	21	0
Riverside	23	7	0	1	0	0	0	0	0	0	31		1	0	0	0	0	0	0	0	0	0	1	0	0
Sacramento	3	2	0	0	0	0	0	0	0	0	5		0	0	0	0	0	0	0	0	0	0	0	0	0
San Benito	10	1	2	0	2	0	0	0	0	0	15		0	0	0	0	0	0	0	0	0	0	0	0	0
San Bernardino	23	4	6	3	1	0	0	0	0	0	37		3	1	3	0	0	0	0	0	0	0	7	0	0
San Diego	20	11	4	0	1	0	0	0	0	0	36		0	0	0	0	0	0	0	0	0	0	0	0	0
San Luis Obispo	27	11	12	6	2	0	0	0	0	0	58		1	1	1	0	1	0	0	0	0	0	4	0	3
San Mateo	16	2	1	0	0	0	0	0	0	0	19		0	0	0	0	0	0	0	0	0	0	0	0	1
San Joaquin	1	0	0	0	1	0	0	0	0	0	2		0	0	0	0	0	0	0	0	0	0	0	0	1
Santa Barbara	53	58	26	19	18	4	0	0	0	1	179		2	1	0	0	4	1	0	0	0	0	8	5	6
Santa Clara	2	2	1	1	0	0	0	0	0	0	6		0	0	0	0	0	0	0	0	0	0	0	0	0
Santa Cruz	8	1	0	0	0	0	0	0	0	0	9		0	0	0	0	0	0	0	0	0	0	0	0	1
Solano	4	2	2	0	2	0	0	0	0	0	10		0	0	0	1	0	0	0	0	0	0	1	0	0
Sonoma	5	5	1	0	0	1	0	0	0	0	12		1	1	1	0	0	0	0	0	0	0	3	0	0
Stanislaus	7	2	2	1	0	0	0	0	0	0	12		0	1	0	0	0	0	0	0	0	0	1	0	0
Tehama	1	16	0	0	0	0	0	0	0	0	17		0	0	0	0	0	0	0	0	0	0	0	0	3
Tulare	45	8	3	4	3	0	0	0	0	0	63		2	0	0	0	0	0	0	0	0	0	2	0	1
Ventura	134	47	37	26	20	12	7	3	0	0	286		6	5	0	0	2	0	1	0	0	0	14	20	14
Yolo	0	0	2	1	0	1	0	0	0	0	4		0	0	0	0	1	0	0	0	0	0	1	0	1
Shasta	1	0	0	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0
Total	937	441	381	413	334	127	38	20	5	2	2,698	23,606	42	18	15	17	16	5	5	2	1	1	122	111	69

Research in the producing of oil, besides improvement in electric power factor, has been directed toward the study of subsurface pressures with pressure bombs. Such studies have resulted in practical operating value in many cases, especially those involving the proper depth for setting the pump.

Decline and/or Increase in Oil and Gas Reserves.—Estimated crude oil reserves were increased by new development at Mountain View and deep-zone development at Montebello and Mount Poso fields. However, these additions to reserves were insufficient to offset the 173,083,319 bbl. of oil produced during the year 1933.

Gas reserves were greatly depleted in all fields and no new gas fields were discovered. The principal sources of natural gas in California are

TABLE 3.—*Comparative Petroleum Statistics for California*

	Barrels		Decrease, 1933 over 1932		
	12-31-32	12-31-33	Total Barrels	Barrels per Day	Per Cent
Crude Production	178,127,794	173,083,319	5,044,475	13,820	2.8
Stocks in Storage:					
Gasoline and engine distillate	13,173,000	11,538,000	1,635,000	4,479	12.4
Natural gasoline	2,419,000	2,204,000	215,000	589	8.9
Kerosene	1,625,000	1,443,000	182,000	499	11.2
Lubricating oils and greases	923,000	916,000	7,000	19	0.8
Gas oil and diesel oil	4,408,000	4,156,000	252,000	690	5.7
Fuel-oil residium and heavy crude	96,676,000	89,731,000	6,945,000	19,027	7.2
All other commodities	48,994,000	45,453,000	3,541,000	9,702	7.2
Total petroleum	168,218,000	155,441,000	12,777,000	35,005	7.6
	Thousands of Barrels				
	Year 1932	Year 1933			
Net supply available to market:					
Gasoline and engine distillate	52,216	56,021	3,805,000[a]	10,425[a]	7.28[a]
Natural gasoline	12,977	11,744	1,233,000	3,378	9.50
Kerosene	5,992	5,538	454,000	1,244	7.58
Lubricating oils and greases	1,500	1,597	97,000[a]	266[a]	6.47[a]
Gas, oil and diesel oil	20,537	20,133	404,000	1,107	1.97
Fuel oil, residium and heavy crude	88,667	85,474	3,193,000	8,748	9.87
Total petroleum	181,889	180,507	1,382,000	3,786	0.76
Indicated market demand					
Gasoline and engine distillate	65,506	63,865	1,641,000	4,495	2.51
Natural gasoline	1,825	1,239	586,000	1,605	32.11
Kerosene	5,845	5,970	125,000[a]	342[a]	2.14[a]
Lubricating oils and greases	1,872	2,063	191,000[a]	523[a]	10.20[a]
Gas, oil and diesel oil	16,368	18,083	1,715,000[a]	4,699[a]	10.48[a]
Fuel-oil residium and heavy crude	78,616	84,435	5,819,000[a]	15,942[a]	7.40[a]
All other commodities	14,675	14,047	628,000	1,721	4.28
Total petroleum	184,707	189,702	4,995,000[a]	13,685[a]	2.70[a]

[a] Increase.

Kettleman Hills North dome and Middle dome, Belridge, Buttonwillow and Ventura Avenue fields, all other fields being in the declining and

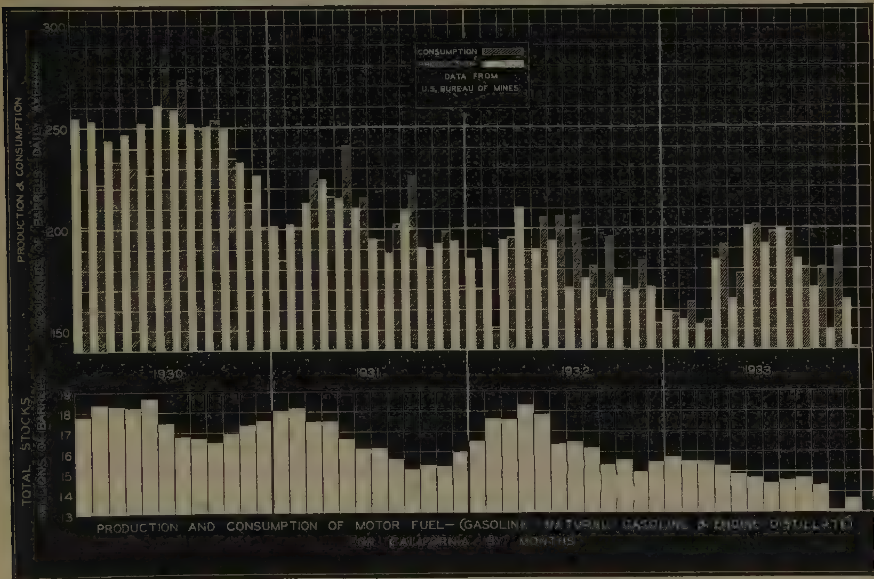

FIG. 1.—PRODUCTION AND CONSUMPTION OF MOTOR FUEL IN CALIFORNIA.

settled productive stage, where gas production is slightly more than that necessary for plant and field use.

Oil and gas production in California as of Dec. 31, 1933, is set forth

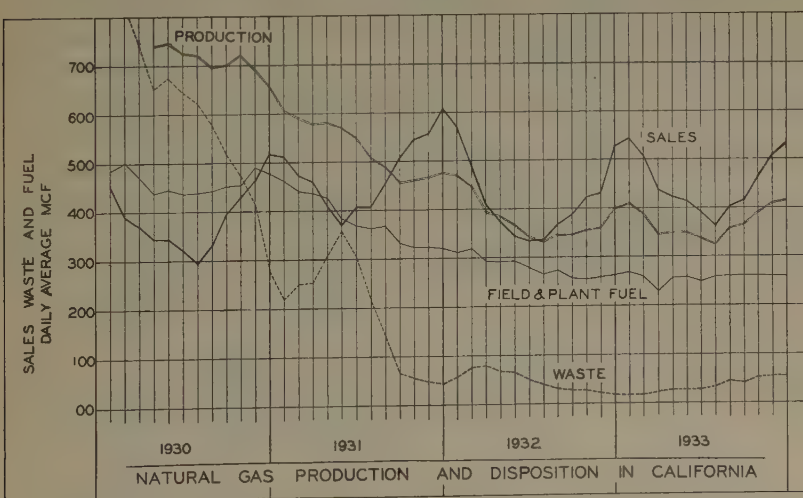

FIG 2.—PRODUCTION AND DISPOSITION OF NATURAL GAS IN CALIFORNIA.

in Table 1, also oil reserves, and a summary of drilling operations in California as of the same date appears in Table 2.

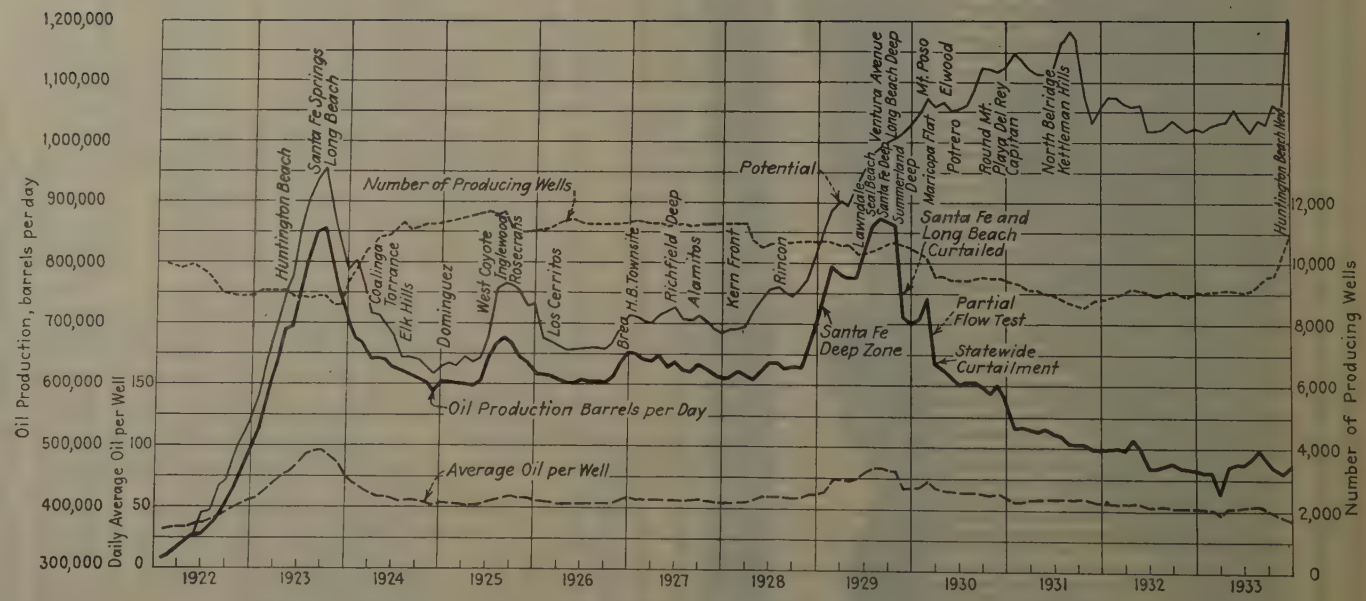

FIG. 3.—RESULTS OF IMPORTANT EVENTS IN CALIFORNIA OIL INDUSTRY SINCE 1921.

Fields are listed to indicate months in which respective production peaks occurred. Number of peaks attained since 1928 has been responsible, with curtailment, for maintenance of state's potential.

Production and Consumption of California Motor Fuel, Etc.—Total crude oil production in California during 1933 amounted to 173,083,319 bbl., a decrease of 5,044,475 bbl. over the year 1932. Total petroleum stocks in storage totaled 155,441,000 bbl. at the end of the year, as compared with 168,218,000 at the close of 1932. This is a decrease of 12,777,000 barrels.

Total motor fuel production for 1933 was 2,082,040 bbl., as compared with 2,199,286 bbl., or 5.3 per cent decline over 1932, while total motor fuel consumption (domestic shipments and exports) amounted to 2,146,106 bbl. in 1933, which is a decrease of 3.0 per cent over the total consumption (2,212,476 bbl.) in 1932.

Table 3 shows comparative petroleum statistics for California during the years 1932 and 1933.

Fig. 1 graphically depicts motor-fuel production and consumption from Jan. 1, 1930 to Jan. 1, 1934, Fig. 2 shows the trend of gas production and utilization during the same period and Fig. 3 shows graphically the results of important events in the oil industry of the state since 1921.

Conclusion.—In California, Federal control, which began in September, terminated more than three years of voluntary curtailment. After four months under the new regime, leaders of the Pacific Coast industry view the future with more confidence, despite the doubts that assailed them prior to the belated but decisive action taken by Federal authorities with respect to code violators. Tightening of the crude curtailment strings, cutting down of refinery runs to market requirements, contracts for millions of barrels of heavy fuel oil for Atlantic seaboard, greatly increased demand assured during 1934 for California asphalt for use in highway construction under the N.R.A., probable increase in fuel-oil trade with Japan, all constitute the nucleus of advantages gained under the Federal administration of the industry. With this improved outlook, it is the consensus of opinion that under the new regime the integrated oil companies on the Pacific Coast will experience their long-hoped-for return to financial security. It is evident from the state of activity manifested toward the end of 1933 that many projects will be carried to profitable fruition during the year 1934, with an optimistic mood prevailing throughout the period.

Acknowledgment

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Oil and Gas Development in Colorado

By C. E. Shoenfelt,* Denver, Colo.

(New York Meeting, February, 1934)

The most important development in an otherwise colorless year in Colorado oil fields was the completion, late in 1933, of a well on Iles dome on the western slope of Colorado, with an initial production of 1100 bbl. of oil. No great amount of activity beyond the drilling of necessary offset wells is to be expected as a result of the completion of a well of this size because the acreage on Iles dome is closely held; there is no pipe line outlet other than to the Texas Company's small refinery at Craig, 24 miles distant; and the market for the oil is limited to the demands of sparsely settled communities in the high mountains.

The Iles field is located on a large dome developed in Mancos shale of Cretaceous age, and having a closure of approximately 400 ft. The structure is highly faulted on the southern end. The first commercial oil well on this dome was completed by the Midwest Refining Co. on the south side of sec. 22-4N.-92W. Oil of 37° gravity was developed in Mancos shale at 2560 ft. and water in the Dakota sandstone at 2630 ft., but a considerable amount of additional oil was found in the shale immediately overlying the Dakota. From 2630 ft., the well produced in 16 hr. 750 bbl. of fluid, 33 per cent of which was water.

Production in the Sundance sand of Jurassic age was found in the Midwest Refining Company's No. 4 Parkinson, in the NE.-SW.-SE. of sec. 22-4N.-92W., and completed on the last day of the year 1926, for an initial production of 450 bbl. of oil at a total depth of 3242 ft. The well completed in 1933 is also a Sundance sand producer and was finished at a depth of 3447 ft. It extends the productive area of the field about a quarter of a mile east.

The Iles field is said to have a potential production of 5000 bbl. of oil a day from its present wells, but for the past year has been held at about 600 bbl. a day.

The most important test, stratigraphically, ever drilled on the western slope of Colorado is the California Company's No. 1 Raven, NW.-SE. of sec. 30-2N.-102W., which had an initial production of 138 bbl. of oil of 32° gravity, in the Weber formation (Pennsylvanian) between 5750 to 6315 ft. It was drilled to 7137 ft., probably near the base of the Weber, and then plugged back to 6315 ft. It was shot quite heavily with nitroglycerin, but failed to respond. While the well can hardly be classified

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as a commercial producer, on account of the small production, its depth, and the cost incident to its drilling, it proves the presence of oil in Pennsylvanian rocks in the area and should lead to the testing of other structures in the vicinity in which Pennsylvanian formations are not so deeply buried.

The Rangely structure is a gentle anticline with approximately 700 ft. of closure and embracing between 19,000 and 20,000 acres above the lowest closing contour. The oldest formation exposed in the center of the structure is the Mancos shale of Cretaceous age.

Since the year 1919, the Rangely field has been producing daily upwards of 75 bbl. of shale oil of 43° gravity, from shallow horizons above the Dakota group. There is no pipe line outlet for the oil, but a small skimming plant in the field, operated by the Raven Oil & Refining Co., is handling the entire output of the field and is selling locally the gasoline produced.

Prior to 1932, several attempts were made to develop commercial oil production in the Dakota sand of Cretaceous age, and in the Morrison and Sundance sands of Jurassic age. Two of these tests discovered large flows of gas in the Dakota sand, but no oil. The best of these completions was the Texas Company's No. 1 Emerald, SW.¼ of sec. 30-2N.-102W., which gaged 60,000,000 cu. ft. of gas per day in the top of the Dakota sand at 3001 feet.

One of the really important tests of the year was the Mountain Fuel Supply Company's No. 2 Florence Wilson on Hiawatha dome in Moffat County. It was drilled to a depth of 7577 ft. and was out of the Wasatch formation of Eocene age, and in the top of the Mesaverde formation of Cretaceous age, at 7224 ft. It was then plugged back and completed as a small gas well in Wasatch sands at 3023 to 3069 ft., 3335 to 3371 ft., and 3676 to 3719 feet.

Table 1.—*Oil and Gas Production in Colorado*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres		
			Oil	Gas	Total
1	Berthoud, *Larimer*	4	510		510
2	Boulder, *Boulder*	31	400		400
3	Florence-Canon City, *Fremont*	72	9,000		9,000
4	Fort Collins, *Larimer*	10	400		400
5	Garcia, *Las Animas*	7		640	640
6	Greasewood, *Weld*	3	200		200
7	Hamilton (Moffat), *Moffat*	10	400		400
8	Hiawatha, *Moffat*	6	3,180		3,180
9	Iles, *Moffat*	9	600		600
10	Model, *Las Animas*	5		2,000	2,000
11	Rangely, *Rio Blanco*	14	320		320
12	Tow Creek, *Routt*	9	200		200
13	Walden, *Jackson*	6	320		320
14	Wellington, *Larimer*	9	1,000		1,000
15	Total		16,530	2,640	19,170

Hiawatha dome, one of six structures in what is known as the Vermillion Creek gas area, is a northeast-southwest structure having 235 ft. of local closure embracing 4400 acres above the lowest closing contour. The Wasatch formation outcrops, and it is in this same formation that the several gas-bearing sands are found. The crest of the dome is practically unfaulted, but several faults are found in the synclines. The field is controlled by the Mountain Fuel Supply Co., which has seven completed gas wells ranging in initial open-flow capacity of from 1,000,000 to 65,000,000 cu. ft. per day per well. Rock pressures range from 600 to 800 lb. per sq. in. In 1929, an outlet for this gas was made when the Western Public Service Corporation constructed 330 miles of pipe line to Salt Lake, Ogden and other Utah towns.

Despite the fact that exploration work in eastern Colorado, east of the Front Range, has so far failed to develop an oil and gas field of major proportions, the results of drilling have been sufficiently encouraging to cause the larger companies to continue geological and geophysical prospecting and not only to continue to hold the acreage acquired three years ago but also to continue the acquisition of new blocks. In the months immediately following the discovery of the Greasewood field (1930) approximately one million acres of leases were taken in eastern Colorado by a number of companies, only a small proportion of which have been released. The total state land, government land, and fee land under lease in eastern Colorado is now estimated at 3,000,000 acres. At the close of 1933, the State of Colorado has leased for oil and gas prospect-

Table 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Per Acre to End of 1933[b]	Per Acre-foot to End 1933	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933
1								300	100	85	*y*
2	589,000	1,000	0	0			0				
3	13,125,000	116,989	91,343	250	1,458		2.4				
4	1,953,635	69,099	49,870	173	4,884	195	16				
5								2,294	274	278	0.75
6	351,198	107,467	52,198	126	1,756	50	47				
7	4,731,639	238,839	204,242	453	11,829	591	37				
8								*y*	1,559	1,467	*y*
9	2,638,799	241,803	210,032	668	4,400	220	37				
10								19	0	0	0
11	342,478	28,595	29,962	104	1,069		26				
12	1,270,827	101,185	86,949	214	6,354		17				
13	133,319	0	0	0	417		0				
14	4,198,771	223,737	176,223	455	4,199	210	21				
15	29,334,266	1,128,714	900,819	2,443					1,935	1,830	

[b] Footnotes to column headings and explanation of symbols are on page 175

ing upwards of 450,000 acres, approximately 85 per cent of which is in the plains country east of the mountains. Rentals accruing to the state from oil and gas leases amounted to about $65,000 in 1933.

Development work in northeast Colorado in 1933 was confined to an area north and east of the Greasewood field, in the vicinity of the towns of Buckingham and New Raymer. Three wells were drilled, of which one was a small gas well and the others were failures.

The gas well, in the SW.-NE.-SE. of sec. 15-7N.-59W., and known as No. 1 St. Anthony, was drilled by the Ramsey Petroleum Co. The Timpas limestone, of Cretaceous age and an important marker in eastern Colorado, was logged at 6165 to 6222 ft. and the top of the so-called Muddy sand (the upper member of the Dakota group) at 6687 ft. When the well had been carried to a total depth of 6695 ft. and bailed down to 3200 ft., it cleaned itself with the pressure of the gas developed in this sand. From 6695 ft., it gaged 6,300,000 cu. ft. of gas per day under 1635 lb. pressure. While blowing open, the gas carried a slight "mist" of greenish brown oil vapor. Drilling was resumed and the top of the horizon generally classified as Dakota was found at 6758 ft. Oil-saturated cores were taken between 6758 and 6761 ft. Casing was run to bottom and perforated through the gas horizon and at the bottom of

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933		Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1933				Character of Gas, Approx. Average during 1933	
		During 1933		At End of 1933						Number of Wells			Average at End of		Gravity A.P.I. at 60° F.					
	Completed to End of 1933	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial	1932	1933	Maximum	Minimum	Weighted Average	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	4					4	4	2,940	2,920			600	x	250					1,120	0.9
2	50	0	1	3			0		2,000								38.6	P		
3	1,200	0	2		105		105		2,200		105						31	P		
4	15	0	4		11		11	4,560	4,535		11				37	34.8		P		
5	14	1	0			8	8		1,600			25	12	11						2
6	8	0	1		3		3	6,680	6,645	3							42	P		
7	12	0	0		12		12	3,880	3,860		12						41	P		
8	8	1	0			8	8	[1]	[1]			850	y	650					1,080	0
9	23	1	0		18		18	3,315	3,295	6	12				35	32		P		
10	6	0	0	6			0	1,004	960			25	11	12					Inert[2]	
11	50	1	0	1	4		4		600		4				52	43		P		
12	15	0	0		15		15		2,600		15				37	35		P		
13	2	0	0	2			0	5,115	5,110						52	50		P		
14	30	0	0		22		22	4,500	4,480		22				37.4	37		P		
15	1,425	4	8	12	190	20	210			9	181									

[1] Commercial gas is produced from irregular and lenticular fresh-water sands of Eocene age at various depths from 1500 to 3500 feet.

[2] 7.9 helium. At Thatcher, Colo., 11 miles distant, The Helium Company of Louisville, Ky., has a $600,000 plant, temporarily shut down, for the extraction of helium from this gas.

the string. Cable tools were installed and the hole cleaned, with the result that it began flowing oil and water. The greatest amount of oil that was produced in any one day was approximately 65 bbl. with which was approximately 80 bbl. of water. The well was finally deepened to 6791 ft., at which depth the water had increased to 390 bbl. a day and the oil had diminished to an almost negligible amount. Early in 1933 this well was plugged back to the gas sand and completed.

The second test drilled by Ramsey Petroleum Co. was on the Scriven farm in the NW. corner of sec. 22-7N.-59W. It was started in August, 1933, and suspended for the winter at 6818 ft. The so-called Muddy sand between 6794 and 6818 ft. was dry and did not respond to two light shots of nitroglycerin. This well is to be deepened in the spring.

The joint test of Continental Oil Co., California Co., Centennial Plains Oil Co. and the Tulsa-Fort Morgan Oil Co., known as No. 1 Anthes, and located in the NE. corner of sec. 24-8N.-59W., was also a failure. It had the Timpas lime marker from 6056 to 6078 ft.; was dry in the so-called Muddy sand at 6523 to 6537 ft.; and dry in the Dakota sand at 6623 to 6658 feet.

One other failure deserves mention because of its location on the eastern edge of the deep Denver Basin on the Buick structure. Little is definitely known concerning the Buick structure. The surface is covered by flat-lying Tertiary beds overlying the Pierre and possibly the Fox Hills formations. Detail mapping is difficult if not impossible. It has been reported, however, that a pronounced magnetometer high

TABLE 1.—(*Continued*)

Line Number	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1	Hygiene	Cre U	S	20	20	A	47	Lakota (Cre L)	4,031
2	Pierre	Cre U	H	Fis		MF		Morrison (Jur)	3,497
3	Pierre	Cre U	H	Fis		T, S	1,193	Fountain (Pen)	1,875
4	Muddy-Dakota	Cre U	S	12	25	A	4	Dakota (Cre U)	4,995
5	Benton	Cre U	H	Fis		D	5	Morrison (Jur)	1,392
6	Muddy-Dakota, Sundance	Cre U	S	9	35	A	5	Lakota (Cre L)	6,913
7		Cre U, Jur	S, S	18,[3] 14	20	D		Sundance (Jur)	4,490
8	Wasatch	Eoc	S	*y*	*x*	D		Mesa Verde (Cre U)	7,577
9	Mancos, Sundance	Cre U, Jur	H, S	9	20	D	5	Sundance (Jur)	3,447
10	Santa Rosa	Tri	S	22	44	D		Fountain (Pen)	2,000
11	Mancos	Cre U	H	Fis		A	45	Weber (Pen)	7,173
12	Mancos	Cre U	H	Fis		A		Thaynes[5] (Tri)	5,310
13	Muddy-Dakota	Cre U	S(?)	*x*[4]		AF	2	Muddy-Dakota	5,115
14	Muddy-Dakota	Cre U	S	12	20	A	8	Morrison (Jur)	4,932
15							1,314		

[3] Figures from recovery indicate 20 per cent.
[4] No samples of the formation have been recovered
This well abandoned in granite.

was mapped and that domal structure was outlined by core drilling.

Prior to 1933, a well was drilled on the structure by J. M. Botts in the SE. corner of sec. 1-8S.-59W., which was abandoned at a depth of 4120 ft. because of mechanical difficulties. In the process of drilling, several shows of oil and gas were developed. Mr. Botts was sufficiently

TABLE 2.—*Summary of Drilling Operations in Colorado*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934									Completed during 1933								Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes							Productive Wells (For Details See Table 1)		
	Total Depths, Ft.									Total Depths, Ft.									
	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	Total		1000–2000	2000–3000	3000–4000	4000–5000	6000–7000	7000–8000	Total		Within Fields	Exploratory
Adams	2	1	2	0	1	0	0	6	0	0	0	0	1	0	0	1	0	0	0
Alamosa	0	2	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Arapahoe	4	1	0	0	1	0	0	6	0	0	0	0	0	0	0	0	0	0	1
Archuleta	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Baca	0	2	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Bent	0	0	1	1	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
Boulder	4	32	13	4	2	2	1	58	0	1	0	0	0	0	0	1	0	0	1
Cheyenne	2	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Crowley	4	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Delta	3	0	0	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Dolores	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Douglas	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Elbert	2	0	1	1	0	0	0	4	0	0	0	1	0	0	0	1	0	0	0
El Paso	6	5	6	1	0	0	0	18	0	0	1	0	0	0	0	1	0	0	0
Fremont	2	1250	2	1	0	0	0	1255	105	0	1	1	0	0	0	2	0	0	1
Garfield	2	2	2	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
Huerfano	1	4	3	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	1
Jackson	0	1	1	4	1	0	0	7	0	0	0	0	0	0	0	0	0	0	1
Jefferson	2	1	2	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Kiowa	3	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Kit Carson	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
La Plata	5	2	5	0	0	0	0	12	0	0	0	1	0	0	0	1	0	0	0
Larimer	9	10	7	46	2	0	0	74	37	0	1	1	0	0	0	2	0	0	2
Las Animas	15	8	2	0	0	0	0	25	8	2	0	0	0	0	0	2	1	1	0
Lincoln	0	3	1	0	0	0	0	4	0	0	0	1	0	0	0	1	0	0	0
Logan	0	0	0	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Mesa	5	2	3	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Moffit	5	17	38	10	1	0	1	72	38	1	0	4	0	0	1	6	1	4	0
Montezuma	2	0	0	2	0	0	0	4	0	0	0	0	1	0	0	1	0	2	0
Montrose	0	0	2	1	1	1	0	5	0	0	0	0	0	0	0	0	0	0	0
Morgan	1	0	0	0	1	2	0	4	0	0	0	0	0	0	0	0	0	0	0
Otero	8	1	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
Park	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1
Prowers	1	5	0	0	1	0	0	7	0	0	1	0	0	0	0	1	0	0	0
Pueblo	8	5	2	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0
Rio Blanco	2	4	2	3	3	0	1	15	4	0	0	0	0	0	1	1	1	0	0
Routt	6	6	23	0	0	0	0	35	15	0	0	0	0	0	0	0	0	0	0
Saguache	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Washington	5	1	0	1	0	0	0	7	0	0	0	0	0	4	0	4	0	1	0
Weld	4	3	0	0	0	10	1	18	3	0	0	0	0	0	0	0	0	0	0
Yuma	3	3	3	0	1	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Totals	120	1375	123	80	17	17	4	1736	210	4	5	9	2	4	2	26	3	8	8

encouraged by these showings to start a rotary test in 1932 in the NW. SE. corner of sec. 7-8S.-58W., which was dry and was abandoned early in 1933 at a total depth of 3650 feet.

Acknowledgments

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Oil and Gas Development in Illinois in 1933*

By Alfred H. Bell,† Urbana, Ill.

(New York Meeting, February, 1934)

Continued low prices and restricted markets for crude oil discouraged drilling activity in Illinois oil fields during 1933. Only 36 wells were completed in the state, the smallest number since 1904, and of these the majority were scattered wildcat wells, only 10 having been drilled in producing fields (Table 2). Production was curtailed approximately 40 per cent for the first half of the year. During July, August, and the early part of September there was no restriction on production. On Sept. 8, under the "code of fair competition for the petroleum industry," the quota of allowable production for Illinois was fixed at 12,000 bbl. per day. The state's production in 1933 was 9 per cent less than in 1932. What it would have been had there been no curtailment of production and if economic conditions had permitted a normal amount of cleaning out and repairs to wells, it is not possible to estimate, but it would no doubt have been considerably more than the actual figure. No new pools or new producing horizons were discovered in 1933, but the deepening of a Robinson sand well in Crawford County to the McClosky "sand" horizon (St. Genevieve limestone of the Lower Mississippian) resulted in a production of 3 bbl. per day (Fred Patchel, Savilla Shipman No. 5, NE. ¼, SW. ¼, sec. 26, T.6N., R.13W., deepened from 1122 to 1388 ft., August, 1933). Considerable parts of the Crawford County field remain to be tested to the McClosky horizon, and, owing to the rapid variations in porosity within short distances, as shown in the Lawrence County field to the south, one test may not be considered as proving or condemning any large area.

The average price of Illinois crude oil in 1933, calculated from the posted prices as published in the *Oil and Gas Journal* and *Oil Weekly*, was $0.862 per barrel. This compares with a calculated average price of $1.032 in 1932 and 0.852 in 1931. The total value of Illinois crude oil produced in 1933 obtained by multiplying the average price (0.862) by the total production (4,227,000 bbl.) was $3,643,674.

Of the 26 wildcat wells drilled in 1933, only one was drilled on known favorable structure. This was the Walmar Oil Company's William Pepple well No. 1, sec. 12, T.4N., R.12W., Hancock County, which tested

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the Warsaw anticline.[1] The lowest horizon tested was the St. Peter sandstone, and fresh water was found in the "Trenton." The total depth was 901 feet.

In the southeastern Illinois field, which has yielded 97 per cent of the state's total production to date, only seven wells were drilled. Six were oil producers having a total initial production of 32 bbl.; one was a gas producer. During 1933 this field produced 90 per cent of the state's total.

The southeastern Illinois field has produced 400,000,000 bbl. of oil and ranks fifth in total production to date in the United States. Available data indicate that probably four-fifths of the original oil is still underground, which would mean a total reserve of 1,600,000,000 bbl. Undoubtedly a substantial quantity will be recoverable by improved methods, possibly as much as 50 per cent of the amount already produced, or 200,000,000 bbl. Increasing attention is being given by the industry to improved recovery methods.

On May 12, 1933, the First Annual Petroleum Conference of Illinois, sponsored by the Illinois-Indiana Petroleum Association, the Illinois State Geological Survey, and the Illinois Chamber of Commerce, was held at Robinson. This conference was devoted to the discussion of improved recovery methods, including air and gas repressuring, and water-flooding. The results of certain studies by the State Geological Survey on these subjects have been published, and the preparation of reports for additional publications is in progress.

The existence of natural water drives in certain areas that resulted in substantial increases in the rate of production on leases located in the path of the advancing flood suggests that artificial water-flooding, such as is practiced in the Bradford field, Pennsylvania, may be applicable to parts of the southeastern Illinois oil field. However, since previously existing statutes required that fresh water be prevented from entering oil sands, new legislation was necessary before tests of artificial water-flooding could be made legally. On June 8, 1933, an amendment to the statute was enacted which permits the injection of water or other fluid into an oil sand for the purpose of recovering oil.

Two actual tests of artificial water-flooding were begun in 1933, one in the Carlyle oil field, Clinton County, by the Ohio Oil Co. and the other in the main Crawford County field (sec. 12, T.7N., R.14W., Oblong Township) by the Tidewater Oil Co. An increased rate of production from three wells surrounding the input well has already been noted in the latter locality.

No new repressuring plants were installed in Illinois fields during 1933, but all of the existing plants continued in operation. As soon as

[1] A. H. Bell: Oil Possibilities of the Warsaw Area, Hancock County, Illinois. Ill. State Geol. Survey Press Bull. Ser., Ill. Petr. No. 24 (Dec., 1932).

economic conditions permit, probably there will be a considerable number of new installations. Compressers are now being installed by the Ohio Oil Co. in the Colmar-Plymouth field in McDonough County.

The figures for production by fields (Table 1) were estimated after taking into consideration the state totals as published by the Bureau of Mines, unpublished statistics on production by company and by county in the files of the Illinois State Geological Survey, for the years 1914–1926 inclusive, and estimated productions for various fields in 1932 and 1933 furnished by the Ohio Oil Co. and Illinois Pipe Line Co.

Some of the data on the Wamac field, Marion, Washington and Clinton counties, were furnished by Mr. H. A. Wheeler, Petro Oil Co., St. Louis, Mo. Data on wells and gas production in the Spanish Needle Creek and Gillespie areas were furnished by the Illinois Power and Light Corporation, Hillsboro, Ill. The figures given for maximum and minimum gravity of oil by fields (Table 1) were from a list of gravities by leases determined in November, 1925, furnished by the Illinois Pipe Line Co., and a weighted average for each field has been estimated. There has been a decrease in average gravity of Illinois oil from 33.2° A.P.I. in 1925 to 31.7° A.P.I. in 1933.

The great majority of Illinois oil wells have also produced casinghead gas and, although the gas pressure is now very low, many wells still produce some gas. In the early life of the southeastern Illinois field gas was supplied for municipal use to about 20 towns and villages in the area, but in recent years the available gas has been used only for power on the leases and for making natural-gas gasoline. It is not possible now to ascertain accurately the extent of the areas that produced casinghead gas, and accordingly the acreage productive of oil only and of oil and gas is combined in Table 1.

The total amount of natural-gas gasoline produced in Illinois to the end of 1932 was 118,902,000 gal. (U. S. Bureau of Mines statistics) and the average yield was 2.3 gal. per 1000 cu. ft. This gives a total amount of gas treated, to the end of 1932, of 51,800,000,000 cu. ft. and compares with a total of 104,586,000,000 cu. ft. of natural gas produced in Illinois for the same period. This total is supposed to include gas used for power on leases but does not include gas wasted.

The total production of natural gas in Illinois according to the definition adopted in this symposium is not known.

The number of natural gasoline plants operating in Illinois was 79 on Jan. 1, 1932, all being of the compression type. (U. S. Bureau of Mines *Inf. Circ.* 6635.) A number of these plants are now shut down or converted into repressuring plants. Approximately 45 are now in operation to produce natural gasoline.

The oil and gas pools of Illinois are listed in Table 1 in geographical order from north to south, except that the southeastern Illinois field is separated from the remainder of the state and appears first.

TABLE 1.—*Oil and Gas Production in Illinois*

Line Number	Field, *County*	Age, Years to End of 1933	Year Abandoned	Area Proved, Acres: Oil + Oil and Gas	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1933	Total Oil Production, Bbl.: During 1932	Total Oil Production, Bbl.: During 1933	Daily Average during Nov., 1933
1	Warrenton-Borton, *Edgar*....	27		100	0	100	25,000±	*y*	730±	2
2	Westfield (Parker Twp.), *Clark, Coles*..............	29		9,000	50	9,050	*x*	*x*	*x*	*x*
3				850	70	920	*x*	*x*	*x*	*x*
4				9,000	0	9,000	*x*	*x*	*x*	*x*
5				1,500	0	1,500	*x*	*x*	*x*	*x*
6	Siggins (Union Twp.), *Cumberland, Clark*............	27		3,580	75	3,655	*x*	*x*	*x*	*x*
7				3,135	55	3,190	*x*	*x*	*x*	*x*
8				435	15	450	*x*	*x*	*x*	*x*
9				855	105	960	*x*	*x*	*x*	*x*
10	York, *Cumberland*...........			310	40	350	*x*	*x*	*x*	*x*
11	Casey, *Clark*................	27		1,925	55	1,980	*x*	*x*	*x*	*x*
12				190	15	205	*x*	*x*	*x*	*x*
13				400	0	400	*x*	*x*	*x*	*x*
14				1,525	15	1,540	*x*	*x*	*x*	*x*
15	Martinsville, *Clark*..........	26		710	155	865	*x*	*x*	*x*	*x*
16				15	20	35	*x*	*x*	*x*	*x*
17				275	35	310	*x*	*x*	*x*	*x*
18				105	0	105	*x*	*x*	*x*	*x*
19				170	0	170	*x*	*x*	*x*	*x*
20				195	0	195	*x*	*x*	*x*	*x*
21				5	0	5	*x*	*x*	*x*	*x*
22	North Johnson, *Clark*........	26		1,320	20	1,340	*x*	*x*	*x*	*x*
23				1,115	0	1,115	*x*	*x*	*x*	*x*
24				160	0	160	*x*	*x*	*x*	*x*
25				820	5	825	*x*	*x*	*x*	*x*
26				215	0	215	*x*	*x*	*x*	*x*
27	South Johnson, *Clark*........	26		1,715	65	1,780	*x*	*x*	*x*	*x*
28				185	5	190	*x*	*x*	*x*	*x*
29				295	0	295	*x*	*x*	*x*	*x*
30				1,675	35	1,710	*x*	*x*	*x*	*x*
31				845	5	850	*x*	*x*	*x*	*x*
32	Bellair, *Crawford, Jasper*.....	26		1,300	5	1,305	*x*	*x*	*x*	*x*
33				1,165	0	1,165	*x*	*x*	*x*	*x*
34				315	0	315	*x*	*x*	*x*	*x*
35				910	0	910	*x*	*x*	*x*	*x*
36	Clark County Division[1]......			19,960	465	20,425	50,000,000	541,000	475,000	1,500
37	Main,[9] *Crawford*.............	27		35,135	515	35,650	*x*	*x*	*x*	*x*
38				340	0	340	*x*	*x*	*x*	*x*
39				33,795	515	34,310	*x*	*x*	*x*	*x*
40				1,000	0	1,000	*x*	*x*	*x*	*x*
41	New Hebron, *Crawford*.......	24		1,350	210	1,460	*x*	*x*	*x*	*x*
42	Chapman, *Crawford*..........	19		1,045	515	1,560	*x*	*x*	*x*	*x*
43	Parker, *Crawford*............	26		1,310	30	1,340	*x*	*x*	*x*	*x*
44	Allison-Weger, *Crawford*......	*y*		1,075	20	1,095	*x*	*x*	*x*	*x*
45	Flat Rock,[10] *Crawford*........	*y*		1,375	545	1,820	*x*	*x*	*x*	*x*
46	Birds, *Crawford, Lawrence*....	*x*		4,370	115	4,485	*x*	*x*	*x*	*x*
47	Crawford Co. Division[6].....	27		45,655	1,945	47,600	136,000,000	1,532,000	1,471,000	4,650

[1] Total of lines 1, 2, 6, 10, 11, 15, 22, 27, 32.
[6] Total of lines 37, 41, 42, 43, 44, 45, 46.
[9] Includes Kibbie, Oblong, Robinson and Hardinsville.
[10] Includes Swearingen Gas.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1933	Year Abandoned	Area Proved, Acres: Oil + Oil and Gas	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1933	Total Oil Production, Bbl.: During 1932	Total Oil Production, Bbl.: During 1933	Daily Average during Nov., 1933
48	Lawrence, *Lawrence* and *Crawford*	27		24,150	1,550	25,700	*x*	*x*	*x*	*x*
49				5,015	35	5,050	*x*	*x*	*x*	*x*
50				2,240	0	2,240	*x*	*x*	*x*	*x*
51				135	1,095	1,230	*x*	*x*	*x*	*x*
52				15,690	220	15,910	*x*	*x*	*x*	*x*
53				4,815	200	5,015	*x*	*x*	*x*	*x*
54				6,370	0	6,370	*x*	*x*	*x*	*x*
55	St. Francisville, *Lawrence*			420	0	420	*x*	*y*	*y*	*y*
56	Lawrence County Division[7]			24,570	1,550	26,120	214,000,000	1,980,000	1,650,000	5,250
57	Allendale, *Wabash*	21		1,660	0	1,660	3,500,000±	240,000±	220,000±	604
58	Total Southeastern Illinois Field[8]			91,845	3,960	95,805	403,500,000	4,293,000	3,816,000	12,304
59	Colmar-Plymouth, *McDonough*, *Hancock*	19.5		2,450	0	2,450	1,800,000	91,200	93,900	257
60	Pike County Gas, *Pike*	28	1920±	0	8,960	8,960	0	0	0	0
61	Jacksonville Gas, *Morgan*	23		30	1,290	1,320	2,100	0	0	0
62	Carlinville, *Macoupin*	24	1925±	30	50	80	*x*	0	0	0
63	Spanish Needle Creek, *Macoupin*	18		0	80	80	0	0	0	0
64	Gillespie (Wyen), *Macoupin*	18		40	0	40	*x*	1,825	1,095	3
65	Gillespie-Benld Gas, *Macoupin*	10		0	80	80	0	0	0	0
66	Staunton, *Macoupin*	17	1919	0	400	400	0	0	0	0
67	Litchfield, *Montgomery*	54	1904	100	0	100	22,000	0	0	0
68	Collinsville, *Madison*	24	1921	40	0	40	715	0	0	0
69	Ayers Gas, *Bond*	11		0	280	280	0	0	0	0
70	Greenville Gas, *Bond*	23	1926±	0	160	160	0	0	0	0
71	Carlyle, *Clinton*	22		915	0	915	3,200,000±	23,712	22,427	60
72	Frogtown, *Clinton*	15		300	0	300	*x*	0	0	*x*
73	Sandoval, *Marion*	24		770	0	770	2,500,000±			
74	Centralia, *Marion*	23		175	0	175	*x*	66,300±	59,800±	160±
75	Wamac, *Marion*, *Clinton*, *Washington*	12		250	0	250	300,000±			
76	Dupo, *St. Clair*	5		670	0	670	733,000	117,000	150,000	400
77	Waterloo, *Monroe*	13	1930	125	0	125	166,000	0	0	0
78	Sparta Gas, *Randolph*	45	*x*	65	100	165	*x*	0	0	0
79	Ava-Campbell Hill, *Jackson*	16		70	370	440	25,000	0	0	0
80	Total Illinois[11]			97,875	15,730	113,605	412,276,000	4,673,000	4,227,000	12,933

[7] Total of lines 48 and 55. [8] Total of lines 36, 47, 56 and 57. [11] Total of lines 58 to 79, inclusive.

TABLE 2.—*Summary of Drilling Operations in Illinois*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934: Dry and/or Near-dry Holes: Total Depths, Ft.: Less 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	Unknown	Total	Productive Wells (For Details, See Table 1)	Completed during 1933: Dry and/or Near-dry Holes: Total Depths, Ft.: Less 1,000	1,000–2,000	2,000–3,000	Total	Productive Wells (For Details, See Table 1)
Adams	0	8	1	0	0	0	0	9	0	0	0	0	0	0
Alexander	0	3	0	0	0	0	0	3	0	0	0	0	0	0
Bond	5	27	8	0	0	0	0	40	14	1	2	0	3	0
Boone	0	2	1	0	0	0	0	3	0	0	0	0	0	0
Brown	5	0	1	0	0	0	0	6	0	0	0	0	0	0
Bureau	0	8	2	0	0	0	0	10	0	0	0	0	0	0
Calhoun	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Carroll	0	2	1	0	0	0	0	3	0	0	0	0	0	0
Cass	0	3	0	0	0	0	0	3	0	0	0	0	0	0
Champaign	3	11	0	0	0	0	0	14	0	0	0	0	0	0

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1933		At End of 1933				
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Completed to End of 1933	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only or Oil and Gas	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	250	x	0.2	0	0	0	0	22	0	0	0	12	0	0	12
2	x	x	x	x	0	0	0	1,607	3		0	382	0	0	382
3	x	x	x	x	0	0	0	184	3		0	y	0	0	y
4	x	x	x	x	0	0	0	1,428	0		0	y	0	0	y
5	x	x	x	x	0	0	0	12	0		0	y	0	0	y
6	x	x	x	x	0	0	0	995	0		0	919	y	0	919
7	x	x	x	x	0	0	0	854	0		0	y	y	0	y
8	x	x	x	x	0	0	0	90	0		0	y	y	0	y
9	x	x	x	x	0	0	0	192	0		0	y	y	0	y
10	x	x	x	x	0	0	0	70	0		0	44	y	0	44
11	x	x	x	x	0	0	0	530	0		0	512	0	0	512
12	x	x	x	x	0	0	0	41	0		0	y	0	0	y
13	x	x	x	x	0	0	0	80	0		0	y	0	0	y
14	x	x	x	x	0	0	0	319	0		0	y	0	0	y
15	x	x	x	x	0	0	0	212	0		0	171	0	0	171
16	x	x	x	x	0	0	0	7	0		0	y	0	0	y
17	x	x	x	x	0	0	0	62	0		0	y	0	0	y
18	x	x	x	x	0	0	0	21	0		0	y	0	0	y
19	x	x	x	x	0	0	0	34	0		0	y	0	0	y
20	x	x	x	x	0	0	0	39	0		0	y	0	0	y
21	x	x	x	0	0	0	0	1	0		0	y	0	0	y
22	x	x	x	x	y	y	y	484	0		0	430	y	0	430
23	x	x	x	0	y	y	y	296	0		0	y	y	0	y
24	x	x	x	x	y	y	y	32	0		0	y	y	0	y
25	x	x	x	x	y	y	y	177	0		0	y	y	0	y
26	x	x	x	x	y	y	y	43	0		0	y	y	0	y
27	x	x	x	x	y	y	y	533	0		0	505	y	0	505
28	x	x	x	x	y	y	y	38	0		0	y	y	0	y
29	x	x	x	x	y	y	y	59	0		0	y	y	0	y
30	x	x	x	x	y	y	y	401	0		0	y	y	0	y
31	x	x	x	x	y	y	y	170	0		0	y	y	0	y
32	x	x	x	x	y	y	y	485	0		0	409	0	0	409
33	x	x	x	x	y	y	y	309	0		0	y	0	0	y
34	x	x	x	x	y	y	y	63	0		0	y	0	0	y
35	x	x	x	x	y	y	y	182	0		0	y	0	0	y
36	2,530	80	0.4	x	y	y	y	4,938	3	10	0	3,384	0	0	3,384
37	x	x	x	x	y	y	y	7,309	2	y	0	5,896	0	0	5,896
38	x	x	x	x	y	y	y	68	0	0	0	y	0	0	y
39	x	x	x	x	y	y	y	7,131	1	y	0	y	0	0	y
40	x	x	x	x	y	y	y	108	1	x	x	x	x	x	
41	x	x	x	x	y	y	y	295	0	x	0	203	0	0	203
42	x	x	x	x	y	y	y	193	0	y	0	94	0	0	94
43	x	x	x	x	y	y	y	255	0	x	0	226	0	0	226
44	x	x	x	x	y	y	y	146	0	x	0	77	0	0	77
45	x	x	x	x	y	y	y	280	0	x	0	164	0	0	164
46	x	x	x	x	y	y	y	682	0	x	0	486	0	0	486
47	3,000	120	x	x	y	y	y	9,021	2	17	0	6,948	0	0	6,948
48	x	x		x	y	y	y	4,381	1	x	x	3,438	y	0	3,438
49	x	x	x	x	y	y	y	1,228	0	x	x	x	x	x	x

[a] Footnotes to column headings and explanations of symbols are on page 175.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.: Per Acre to End of 1933[b]	Average Oil Production, Bbl.: Per Acre-foot to End of 1933	Average Oil Production, Bbl.: Per Well Daily during Nov., 1933	Total Gas Production, Millions Cu. Ft.: To End of 1933	Total Gas Production: During 1932	Total Gas Production: During 1933	Total Gas Production: Maximum Daily during 1933	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only or Oil and Gas	At End of 1933: Producing Oil and Gas[c]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing
50	x	x	x	x	y	y	y	473	0	x	x	x	x	x	x
51	x	x	x	x	y	y	y	201	0	x	x	x	x	x	x
52	x	x	x	x	y	y	y	2,978	0	x	x	x	x	x	x
53	x	x	x	x	y	y	y	820	0	x	x	x	x	x	x
54	x	x	x	x	y	y	y	832	1	x	x	x	x	x	x
55	y	x	x	0	0	0	0	54	0	y	x	45	x	x	45
56	8,850							4,435	1	36	x	3,483	y	y	3,483
57	2,100	105±	1.73	0	0	0	0	405	0	3	0	355	0	0	355
58	4,390		0.87	x	y	y	y	18,799	6	66		14,170	y	0	14,170
59	735	35	0.75	0	0	0	0	450	0	0	0	343	0	0	343
60				x	0	0	0	68	0	0	0	0	0	0	0
61	70	14±	0	x	x	x	x	53	3	y	y	0	0	y	y
62	x	x	0	x	0	0	0	8	0	0	0	0	0	0	0
63	0	0	0	14.44	3.43	0±	0±	7	0	0	0	0	0	0	0
64	x	x	0.75	0	0	0	0	11	0	0	0	4	0	0	4
65	0	0	0	135.8	14.6	6.53	0.06	4	0	0	0	0	0	0	0
66	0	0	0	1,050	0	0	0	18	0	0	0	0	0	0	0
67	220	x	0	x	0	0	0	17	0	0	0	0	0	0	0
68	x	x	0	0	0	0	0	5	0	0	0	0	0	0	0
69	0	0	0	x	y	y	y	10	0	0	0	0	0	7	7
70	0	0	0	x	0	0	0	4	0	0	0	0	0	0	0
71	3,500±	175±	0.6	0	0	0	0	164	0	0	0	98	0	0	98
72	x	x	0	0	0	0	0	12	0	0	0	0	0	0	0
73	3,250±	162±	y	0	0	0	0	122	0	0	13	40	0	0	40
74	x	x	y	0	0	0	0	22	0	x	x	x	0	0	x
75	1,200±	60±	1±	0	0	0	0	103	0	25	0	60	0	0	60
76	1,100	22	7.0	0	0	0	0	225	0	15	0	57	0	0	57
77	1,328	y	0	0	0	0	0	23	0	0	0	0	0	0	0
78	x	x	0	x	0	0	0	20	0	0	0	0	0	0	0
79	35	x	0	x	0	0	0	35	0	0	0	0	0	0	0
80	4,220		0.87	x	y	y	y	20,180	9	106	y	14,772	y	7±	14,779

TABLE 2.—(*Continued*)

County	Completed Prior to Jan. 1, 1934: Dry and/or Near-dry Holes, Total Depths, Ft.: Less 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	Unknown	Total	Productive Wells (For Details, See Table 1)	Completed during 1933: Dry and/or Near-dry Holes, Total Depths, Ft.: Less 1,000	1,000–2,000	2,000–3,000	Total	Productive Wells (For Details, See Table 1)
Christian	1	6	1	0	0	0	0	8	0	0	0	0	0	0
Clark	332	13	9	1	0	0	507	862	3,330	0	1	0	1	3
Clay	0	3	6	0	0	0	0	9	0	0	0	0	0	0
Clinton	6	83	3	0	0	0	2	94	180	0	0	0	0	0
Coles	20	9	6	0	0	0	4	39	127	1	1	0	2	0
Cook	0	183	34	0	0	0	0	217	0	0	0	0	0	0
Crawford	212	261	3	0	1	0	914	1,391	9,405	0	7	0	7	3
Cumberland	68	8	4	0	0	0	27	107	974	0	0	0	0	0
De Kalb	0	8	1	0	0	0	0	9	0	0	0	0	0	0
De Witt	0	1	0	0	0	0	0	1	0	0	0	0	0	0

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft. — Bottoms of Productive Wells	Average Depth, Ft. — To Top of Productive Zone	Oil Production Methods at End of 1933 — Number of Wells — Flowing	Number of Wells — Pumping	Number of Wells — Gas-lift	Number of Wells — Air-lift	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e] — Initial	Average at End of — 1932	Average at End of — 1933	Character of Oil,[1] Approx. Average — Gravity A. P. I. at 60° F. — Maximum	Gravity — Minimum	Gravity — Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas Approx. Average during 1933 — B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
1	215	159	0	12	0	0		x	x	x	x	x	x	y			
2			0	382	0	0		200±	x	x	38.4	28.3	34.0	y	M	x	x
3	376	281	0	y	0	0		x	x	x	y	y	30.0	y	M	x	x
4	446	334	0	y	0	0		x	x	x	y	y	33.5	y	M	x	x
5	2,568	2,265	0	y	0	0		x	x	x	y	y	37.0	y	M	x	x
6			0	919	0	0	A2	x	x	x	36.9	27.4	33.0	y	M	x	x
7	465	367	0	y	0	0		x	x	x	y	y	(34.0)	y	M	x	x
8	562	478	0	y	0	0		x	x	x	y	y	(33.6)	y	M	x	x
9	590	556	0	y	0	0		x	x	x	y	y	(25.7)	y	M	x	x
10	680	588	0	44	0	0		x	x	x	33.9	30.0	(30.3)	y	M	x	x
11			0	512	0	0	[2]	x	x	x	37.2	27.2	29.2	y	M	x	x
12	358	263	0	y	0	0		x	x	x	y	y	(31.9)	y	M	x	x
13	426	309	0	y	0	0		x	x	x	y	y	(30.1)	y	M	x	x
14	505	444	0	y	0	0		x	x	x	y	y	(33.6)	y	M	x	x
15			0	171	0	0	A2	x	x	x	37.5	30.2	36.8	y	M	x	x
16	411	255	0	y	0	0		x	x	x	y	y	y	y	y	x	x
17	511	449	0	y	0	0		x	x	x	y	y	y	y	y	x	x
18	506	477	0	y	0	0		x	x	x	y	y	y	y	y	x	x
19	1,418	1,340	0	y	0	0		x	x	x	y	y	(38.9)	y	M	x	x
20	1,596	1,553	0	y	0	0		x	x	x	y	y	y	y	y	x	x
21	2,830	2,708	0	y	0	0		x	x	x	y	y	(39.6)	y	M	x	x
22			0	430	0	0		x	x	x	36.2	27.7	31.0	y	M	x	x
23	486	416	0	y	0	0		x	x	x	y	y	y	y	y	x	x
24	451	314	0	y	0	0		x	x	x	y	y	y	y	y	x	x
25	508	465	0	y	0	0		x	x	x	y	y	y	y	y	x	x
26	554	534	0	y	0	0		x	x	x	y	y	y	y	y	x	x
27			0	505	0	0		x	x	x	35.1	28.5	32.2	y	M	x	x
28	549	392	0	y	0	0		x	x	x	y	y	y	y	y	x	x
29	518	453	0	y	0	0		x	x	x	y	y	y	y	y	x	x
30	570	489	0	y	0	0		x	x	x	y	y	y	y	y	x	x
31	618	598	0	y	0	0		x	x	x	y	y	(28.5)	y	M	x	x
32			0	409	0	0	AG2	x	x	x	35.6	27.3	33.7	y	M	x	x
33	726	561	0	y	0	0		x	x	x	y	y	(32.4)	y	M	x	x
34	907	817	0	y	0	0		x	x	x	y	y	y	y	y	x	x
35	920	886	0	y	0	0		x	x	x	y	y	(37.0)	y	M	x	x
36			0	3,384	0	0	G1 A7 AG13	x	x	x	39.6	25.8	33.0			x	x
37			0	5,896	0	0	[3]	425±	y	y	36.8	25.1	33.0	x	M	960	2.5
38	822	508	x	x	x	x	x	x	x	x	y	y	y	x	y	x	x
39	960	900	0	y	y	x	[4]	425±	y	y	36.8	25.1	32.8	x	M	960	2.5
40	1,416	1,337	0	108	0	0		x	x	x	x	x	x	x	x	x	x
41	975	940	0	203	0	0	G2	x	x	x	35.0	24.3	30.1	x	x	x	x
42	1,015	995	0	94	0	0	AG1	x	x	x	x	x	x	x	x	x	x
43	1,025	1,000	0	226	0	0		x	x	x	x	x	x	x	x	x	x
44	930	912	0	77	0	0		x	x	x	30.4	22.6	29.5	x	x	x	x
45	945	935	0	164	0	0		x	x	x	26.6	20.1	22.5	x	x	x	x
46	950	930	0	486	0	0	A7	x	x	x	34.1	26.5	31.3	x	x	x	x
47	x	x	0	6,948	0	0	[5]	425±	y	y	38.6	19.6	32.5	x	M	960	2.5

[2] G1, A3, AG11. [3] G15, A24, AG20, W1. [4] G15, A24, AG20. [5] G17, A31, AG21, W1.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1933, Number of Wells: Flowing	Number of Wells: Pumping	Number of Wells: Gas-lift	Number of Wells: Air-lift	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1932	Average at End of 1933	Character of Oil,[l] Approx. Average, Gravity A. P. I. at 60° F.: Maximum	Gravity: Minimum	Gravity: Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas Approx. Average during 1933: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
48			0	3,438	0	0	A1	650±	x	x	39.3	26.7	32.9	x	M	x	2.4
49	1,000	800	0	x	0	0		x	x	x	x	x	x	x	x	x	x
50	1,265	1,250	0	x	0	0		x	x	x	x	x	x	x	x	x	x
51	1,345	1,330	0	x	0	0		x	x	x	x	x	x	x	x	x	x
52	1,430	1,400	0	x	0	0		600	x	x	x	x	x	x	x	x	x
53	1,580	1,560	0	x	0	0		650	x	x	x	x	x	x	x	x	x
54	1,710	1,700	0	x	0	0		x	x	x	x	x	x	x	x	x	x
55	1,865	1,843	0	45	0	0		600	x	x	37.3	37.3	37.3	x	x	x	x
56				3,483													
57	1,460	1,425	0	355	0	0	G1	x	x	x	35.9	24.1	35.1	x	x		
58				14,170	0	0	G19 A38 AG34 W1	x	x	x	39.3	20.1	33.1	y	M	y	2.4
59	468	447	0	343	0	0		x	x	x	x	x	37.3	x	y		
60	275	265	0	0	0	0		x	x	x						x	x
61	330	335	0	0	0	0		x	x	x	x	x	x	x	y	898	0.05
62	398	380	0	0	0	0		135	x	x	x	x	±27.7	x	y	x	x
63	405	385	0	0	0	0		y	y	y						y	y
64	670	650	0	4	0	0		x	x	x	x	x	29.2	x	y		
65	555	542	0	0	0	0		155	y	y						788	y
66	491	461	0	0	0	0		145	x	x						x	x
67	674	664	0	0	0	0		x	x	x	x	x	21.7	x	y	x	x
68	1,400	1,305	0	0	0	0		x	x	x	x	x	x	x	x	x	x
69	945	940	0	0	0	0		x	y	y						x	x
70	993	927	0	0	0	0		x	x	x						x	Dry
71	1,055	1,035	0	98	0	0	W3	x	x	x	37.0	34.2	35.2	x	x		
72	957	950	0	0	0	0		x	x	x	y	y	31.9	x	x		
73	1,560	1,540	0	40	0	0		x	x	x	35.1	32.7	34.5	x	x		
74	1,150	1,130	0	x	0	0		x	x	x	35.0	31.0	32.3	x	x		
75	760	720	0	60	0	0		x	x	x	30.8	29.3	30.2	x	P		
76	601	551	0	57	0	0		x	x	x	y	y	32.7	x	x		
77	460	410	0	0	0	0		x	x	x	30.1	29.5	30.0	x	x		
78	857	850	0	0	0	0		x	x	x	x	x	x	x	x	x	x
79	798	780	0	0	0	0		115	x	x	x	x	x	x	x	x	x
80			0	14,772	0	0	G19 A38 AG34 W4										

d,l Footnotes to column headings are on page 175. Following are special definitions of *d* and *l* for application to this table.

d W, water; G, gas; A, air; AG, air-gas mixture. Numbers in this column indicate numbers of injection wells.

l All gravities given (except those in parentheses) were from data for the year 1925 furnished by the Illinois Pipe Line Co. Gravities in parentheses are for particular samples; see Illinois State Geol. Survey Bull. 54 Table 3. The values have been converted from Baumé to A.P.I. gravities.

TABLE 1.—(*Continued*)

Line Number	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested To End of 1933: Name	Depth of Hole, Ft.
1	Unnamed	Pen	S	Por	x	ML	0	Pen.	715
2	See below					D	99	Trenton (Ord)	2,918
3	Shallow gas sand	Pen	S	Por	36	D			
4	Westfield lime	Mis L	L	Por, Cav	x	D			
5	Trenton	Ord	L	Por	x	D			
6	See below					D	28	Dev. limestone	2,010
7	First Siggins sand	Pen	S	Por	x	D			
8	Second and Third Siggins sand	Pen	S	Por	x	D			
9	Lower Siggins sand	Pen	S	Por	x	D			
10	York sand	Pen	S	Por	x	AM	2		960
11	See below					AM	20	Lower Miss.	808
12	Upper gas sand	Pen	S	Por	x	AM	5		
13	Lower gas sand	Pen	S	Por	x	AM	12		
14	Casey sand	Pen	S	Por	x	AM	20		
15	See below					D	5	Trenton (Ord)	2,830
16	Shallow sands	Pen	S	Por	x	D	1		
17	Casey sand	Pen	S	Por	x	D	5		
18	Martinsville "sand"	Mis L	L	Por	x	D	1		
19	Capper	Mis L	S	Por	x	D	1		
20	"Niagaran"	Dev	L	Por	x	D	3		
21	Trenton	Ord	L	Por	x	D	1		
22	See below					AM	16	Mis	965
23	Claypool sand	Pen	S	Por	x	AM	12		
24	Shallow	Pen	S	Por	x	AM	4		
25	Casey	Pen	S	Por	x	AM	12		
26	Upper Partlow	Pen	S	Por	x	AM	16		
27	See below					AM	29	Mis	1,160
28	Claypool sand	Pen	S	Por	x	AM	3		
29	Casey	Pen	S	Por	x	AM	11		
30	Upper Partlow	Pen	S	Por	x	AM	29		
31	Lower Partlow	Pen	S	Por	x	AM	10		
32	See below					AM	14	Lower Mis	1,471
33	"500-ft sand"	Pen	S	Por	x	AM	14		
34	"800-ft sand"	Pen	S	Por	x	AM	3		
35	"900-ft sand"	Mis U	S	Por	x	AM	12		
36					33±		213		
37	See below						200±	Trenton	4,620
38	Shallow sand	Pen	S	Por	x	ML	x		
39	Robinson sand	Pen	S	Por	25±	ML	167	Trenton	4,620
40	Oblong	Mis	S or L	Por	x	A, ML	23	Miss	1,479
41	Robinson sand	Pen	S	Por	x	ML	5	L. Miss	2,056
42	Robinson sand	Pen	S	Por	x	ML	10	Miss	2,279
43	Robinson sand	Pen	S	Por	x	ML	10	Pen?	1,127
44	Robinson sand	Pen	S	Por	x	ML	6	Pen	1,041
45	Robinson (Flat Rock)	Pen	S	Por	x	ML	8	Pen	1,032
46	Robinson sand	Pen	S	Por	x	ML	12	L. Miss	1,731
47	Robinson—Oblong—Shallow	Pen, Mis	S	Por	25±	ML	251	Trenton	4,620
48	See below					A	83	St. Peter	5,190
49	Bridgeport sand	Pen	S	Por	40	A	19		
50	Buchanan	Mis U	S	Por	15	A	3		
51	"Gas" sand	Mis U	S	Por	15	A	5		
52	Kirkwood	Mis U	S	Por	30	A	10		
53	Tracy	Mis U	S	Por	20	A	11		
54	McClosky	Mis L	L	Por	10	A	23		

TABLE 1.—(*Continued*)

Line Number	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested To End of 1933: Name	Depth of Hole, Ft.
55	Kirkwood	Mis U	S	Por	22	ML	0	Miss	1,900
56							83		
57	Biehl sand	Pen	S	Por	35±	AM	43	Miss. (St. Gen.)	2,228
58							590		
59	Hoing sand, Devonian LS	Dev	S, H, LS	Por	21	A	0	Trenton (Ord)	805
60	Niagaran	Sil	L	Por	10	A	0	St. Peter	893
61	Gas sand	Pen, Mis	S, H, SL	Por	5	ML	8	Trenton	1,390
62	Unnamed	Pen	S	Por	*x*	A	0	Pen	410
63	Unnamed	Pen	S	Por	*x*	D	1	Pen	495
64	Unnamed	Pen	S	Por	*x*	T	9	Trenton	2,560
65	Unnamed	Pen	S	Por	*x*	A	0	Pen	575
66	Unnamed	Pen	S	Por	*x*	A	0	Trenton	2,371
67	Unnamed	Pen	S	Por	*x*	D	0	Pen	681
68	Trenton	Ord	L	Por	20	ML	0	Trenton	1,500
69	Unnamed	Mis U	S	Por	5	A	0	L. Mis	1,150
70	Lindley	Mis U	S	Por	66	A	0	Mis	1,065
71	Carlyle	Mis U	S	Por	20	A	17	Sil	2,620
72	Carlyle	Mis U	S	Por	7	D	0	Carlyle *y*	962±
73	Benoist	Mis U	S	Por	20±	D	7	Mis	1,732
74	Dykstra, Wilson, Benoist	Pen, Mis U	S	Por	20	D, ML	6	L. Mis	1,779
75	Petro	Pen	S	Por	20	D	0	Benoist	1,484
76	Trenton	Ord	L	Por, Cav	50	A	0	Trenton	819
77	Trenton	Ord	L	Por	50	A	19	Trenton	845
78	Sparta gas sand	Mis U	S	Por	7	D	4	U. Mis	985
79	Unnamed	Mis U	S	Por	18	A	*y*	Dev	2,530
80							661±		

TABLE 2.—(*Continued*)

County	Completed Prior to Jan. 1, 1934: Dry and/or Near-dry Holes, Total Depths, Ft.: Less 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	Unknown	Total	Productive Wells (For Details, See Table 1)	Completed during 1933: Dry and/or Near-dry Holes, Total Depths, Ft.: Less 1,000	1,000–2,000	2,000–3,000	Total	Productive Wells (For Details, See Table 1)
Douglas	11	7	1	0	0	0	0	19	0	0	0	0	0	0
Du Page	0	7	14	0	0	0	0	21	0	0	0	0	0	0
Edgar	8	6	4	0	0	0	0	18	22	0	0	0	0	0
Edwards	0	7	3	0	0	0	0	10	0	0	0	0	0	0
Effingham	1	5	1	0	0	0	0	7	0	0	0	0	0	0
Fayette	0	8	3	0	0	0	0	11	0	0	0	0	0	0
Franklin	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Fulton	2	11	3	0	0	0	0	16	0	0	0	0	0	0
Gallitin	1	14	1	2	0	0	0	18	0	0	0	0	0	0
Greene	0	5	0	0	0	0	0	5	0	0	0	0	0	0
Grundy	0	4	1	0	0	0	0	5	0	0	0	0	0	0
Hamilton	0	2	1	0	0	0	0	3	0	0	0	0	0	0
Hancock	0	3	0	0	0	0	0	3	17	1	0	0	1	0
Hardin	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Henderson	0	2	0	0	0	0	0	2	0	0	0	0	0	0
Henry	2	17	3	0	0	0	0	22	0	0	0	0	0	0

TABLE 2.—(*Continued*)

County	Completed Prior to Jan. 1, 1934									Completed during 1933				
	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes				Productive Wells (For Details, See Table 1)
	Total Depths, Ft.							Total		Total Depths, Ft.			Total	
	Less 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	Unknown			Less 1,000	1,000–2,000	2,000–3,000		
Iroquois	2	4	0	0	0	0	0	6	0	0	0	0	0	0
Jackson	22	32	2	0	0	0	0	56	35	0	0	0	0	0
Jasper	4	11	2	0	0	0	0	17	17	0	0	0	0	0
Jefferson	0	7	5	0	0	0	0	12	0	0	0	0	0	0
Jersey	0	2	0	0	0	0	0	2	0	0	0	0	0	0
Jo Daviess	0	2	0	0	0	0	0	2	0	0	0	0	0	0
Johnson	0	3	2	0	0	0	0	5	0	0	0	0	0	0
Kane	0	10	11	0	0	0	0	21	0	0	0	0	0	0
Kankakee	1	4	0	0	0	1	0	6	0	0	0	0	0	0
Kendall	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Knox	1	10	3	0	0	0	0	14	0	0	0	0	0	0
Lake	0	27	7	0	0	0	0	34	0	0	0	0	0	0
La Salle	0	19	7	0	0	0	0	26	0	0	0	0	0	0
Lawrence	83	301	69	0	0	1	56	510	4,519	0	0	0	0	1
Lee	0	9	1	0	0	0	0	10	0	0	0	0	0	0
Livingston	0	10	3	0	0	0	0	13	0	0	0	0	0	0
McDonough	0	5	1	0	0	0	0	6	433	0	0	0	0	0
McHenry	0	3	3	0	0	0	0	6	0	0	0	0	0	0
McLean	0	3	2	0	0	0	0	5	0	0	0	0	0	0
Macon	0	6	7	0	0	0	0	13	0	0	0	0	0	0
Macoupin	24	0	4	0	0	0	0	28	48	0	0	0	0	0
Madison	2	13	0	4	0	0	0	19	5	0	0	0	0	0
Marion	3	28	4	0	0	0	0	35	240	1	0	0	1	0
Marshall	0	2	0	0	0	0	0	2	0	0	0	0	0	0
Mason	0	2	0	0	0	0	0	2	0	0	0	0	0	0
Mercer	0	4	0	2	0	0	0	6	0	1	0	0	1	0
Monroe	19	2	1	0	0	0	0	22	23	0	0	0	0	0
Montgomery	5	7	2	1	0	0	0	15	17	0	0	0	0	0
Morgan	21	6	0	1	0	0	0	28	53	1	0	0	1	3
Moultrie	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Ogle	0	4	2	0	0	0	0	6	0	0	0	0	0	0
Peoria	0	8	0	0	0	0	0	8	0	0	0	0	0	0
Perry	0	20	0	2	0	0	0	22	0	0	0	0	0	0
Piatt	0	4	1	0	0	0	0	5	0	0	0	0	0	0
Pike	12	0	0	0	0	0	0	12	68	0	0	0	0	0
Pope	1	2	0	2	0	0	0	5	0	0	0	0	0	0
Pulaski	0	2	1	0	0	0	0	3	0	0	0	0	0	0
Putnam	0	4	0	0	0	0	0	4	0	0	0	0	0	0
Randolph	10	12	0	0	0	0	0	22	20	0	0	0	0	0
Richland	4	2	0	0	0	0	0	6	0	0	0	1	1	0
Rock Island	1	10	4	0	0	0	0	15	0	0	0	1	1	0
St. Clair	15	3	0	0	0	0	0	18	225	0	0	0	0	0
Saline	0	19	6	1	0	0	0	26	0	0	0	0	0	0
Sangamon	1	2	2	0	0	0	0	5	0	2	0	0	2	0
Schuyler	23	10	0	0	0	0	0	33	0	0	1	0	1	0
Scott	2	1	0	0	0	0	0	3	0	0	0	0	0	0
Shelby	0	11	0	0	0	0	0	11	0	0	1	0	1	0
Stark	0	0	2	0	0	0	0	2	0	0	0	0	0	0
Stephenson	0	2	0	0	0	0	0	2	0	0	0	0	0	0
Tazewell	0	2	2	0	0	0	0	4	0	0	0	0	0	0
Union	0	3	4	0	0	0	0	7	0	0	0	0	0	0
Vermilion	2	10	0	0	0	0	0	12	0	0	0	0	0	0
Wabash	2	167	10	0	0	0	145	324	405	0	0	1	1	0
Warren	0	2	2	0	0	0	0	4	0	0	0	0	0	0
Washington	4	14	0	0	0	0	0	18	3	0	0	0	0	0
Wayne	0	5	0	0	0	0	0	5	0	0	0	0	0	0
White	0	4	2	0	0	0	0	6	0	0	0	0	0	0
Whiteside	0	6	0	0	0	0	0	6	0	0	0	0	0	0
Will	0	32	0	0	0	0	0	32	0	1	1	0	2	0
Williamson	0	6	0	0	0	0	0	6	0	0	0	0	0	0
Winnebago	0	15	1	0	0	0	0	16	0	0	0	0	0	0
Woodford	0	3	2	0	0	0	0	5	0	0	0	0	0	0
Total	941	1,658	294	16	1	2	1,655	4,567	20,180	9	15	3	26	10

Table 3.—*Production of Crude Oil in Illinois in 1933 by Months*[a]
Thousands of Barrels

	Total	Per Day
January	297	10
February	263	9
March	314	11
April	284	9
May	313	11
June	357	12
July	404	14
August	411	14
September	412	14
October	406	14
November	388	13
December	378	13
Total	4227	11.6
Year 1932	4673	12.8

[a] U. S. Bureau of Mines.

The Petroleum Industry in Indiana in 1933

W. N. Logan* and Paul Simpson,† Indianapolis, Indiana

(New York Meeting, February, 1934)

There was less activity in the petroleum industry in Indiana in 1933 than in previous years, owing largely to adverse market conditions. The only development of any consequence was for oil in Perry and Vanderburgh counties in southwestern Indiana, a few gas wells being brought in in Jay County in northeastern Indiana. Indications are that there will be more activity in southwestern Indiana in 1934. Little change may be expected in northeastern Indiana.

One hundred and sixty wells were drilled in Indiana in 1933, of which 57 were dry, 44 produced oil, 38 produced gas and 21 either were not completed or information on them was lacking. There were 153 wells abandoned and plugged in 1933, as compared to 205 in 1932.

Southwestern Indiana

This area centers about Gibson County and is the principal source of oil and gas production in the state. Production is from the Lower Pennsylvanian and Upper Mississippian formations. Oil production for 1932 was approximately 847,000 bbl. and for 1933 was 804,000 bbl. Gas production for 1933 was 942,000,000 cubic feet.

The Siosi field, in southwestern Vigo County and northwestern Sullivan County, discovered six years ago, produced approximately 244,000 bbl. in 1932 and 223,000 bbl. in 1933. Production is from Devonian and Silurian formations. The oil is high gravity, but contains considerable sulfur.

The Shelburn and other small pools in central Sullivan County produced approximately 68,000 bbl. in 1932 and 2,000 bbl. less in 1933. Production is from one or more of five horizons in the Pottsville and is obtained at 600 to 800 ft. This area also produces approximately 19,000,000 cu. ft. of gas a year, supplying the city of Sullivan. The field is over 20 years old.

The Gibson-Pike County area, made up of many small pools, including several in southern Knox and southwestern Daviess counties, produced approximately 486,000 bbl. in 1932 and 450,000 bbl. in 1933. This production is from the Mansfield sandstone of Pennsylvanian and/or

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† State Gas Supervisor, Indiana, until February, 1934.

Chester and St. Louis of Mississippian age. Wells range in depth from 700 to 1800 ft. In 1932 there was 942,700,000 cu. ft. of gas removed from this area and 902,000,000 cu. ft. in 1933. The gas production is from the same horizons as the oil. Parts of this area have been producing commercially for more than 30 years.

The Vanderburgh County pool produced approximately 29,000 bbl. in 1932 and 67,000 bbl. in 1933. Production is from the Mansfield sandstone at around 900 ft. The field was opened early in 1932.

Three small pools in eastern Spencer and western Perry counties produced approximately 34,000 bbl. in 1933 and about 19,000 in 1932. Production is from the Chester. Wells range from 330 to 1100 ft. deep.

Northeastern Indiana

Since the removal of pipe lines from the old Trenton field, it is very difficult to obtain production records. Local markets absorb a part of the potential supply of both oil and gas, but an estimate of the amount would not be accurate. Gas consumption is confined almost entirely to the farms near the location of the well and small towns. The ratio of wells abandoned and plugged to those drilled exceeds 10 to 1.

South of the Trenton field proper in Decatur County, considerable gas is still being produced from the Trenton at around 920 ft.; 190 wells produced 141,000,000 cu. ft. of gas in 1933, and 159,000,000 cu. ft. in 1932. The gas field in eastern Monroe County still is not marketing any gas.

Development and Exploration during 1933

Very little exploratory or wildcat drilling took place in Indiana during the first six or seven months. Most of the operations consisted of development of already proven acreage. Several inside locations were drilled in the Siosi field in Vigo County. A number of tests have gone down in this vicinity and in Sullivan County, searching for another field similar to the Siosi. The shallow gas field in northern Knox County was extended north and east by several completions, and late in the year oil in commercial quantities was found. So far, production here is limited to sandstones of Lower Pennsylvanian age, probably in the Brazil group. Two disappointing gas tests were made in the old Lyons field in Greene County, but from existing information the locations seemed poorly advised. Only small flows of gas were obtained in the Devonian limestone at about 1800 feet.

The Francisco gas field in Gibson County was practically delineated to the east and south. Competitive property-line drilling, coupled with competitive production of gas, have practically ruined the field. Coning and rapid water encroachment have resulted in abandonment of many of the wells. There is a chance that production in the "Brown" and

may be extended to the south for some distance, as the "subsurface" structure holds up in that direction. At present, two wells have been deepened to a horizon in the St. Louis limestone, reported as producing both oil and gas in paying quantities.

The Alford gas field in Pike County has been extended north and east until at present the field is more than three miles long. Production here comes largely from the Brown sand of Lower Chester age, at about 1100 ft. in depth. Deeper drilling recently has shown encouraging results. Here again, faulty operating and drilling technique, poor equipment and unwise offset drilling threaten to shorten greatly the life of the field.

The Vanderburgh County field, opened in 1932, has been developed rapidly, with some 30 completions during the year. The only sand bodies found productive, so far, correlate as horizons in the Mansfield or Pottsville sandstone. Average depth is near 900 ft., with a few wells continued to lower sands when too light to save or dry. Flush production seldom yields 75 bbl. No definite limits have been established for the field.

Several wildcat wells have been drilled in Perry and Spencer counties, but no new fields were discovered during 1933. The Bristow, Rock Hill and Troy fields have been extended and their production increased because of the establishment of a market for the oil. There will be several additional wildcat wells drilled in Spencer County during 1934, if one may judge by leasing activities and locations made.

A revival of activity in southern Harrison County has occurred recently. The general productive area around Laconia still supplies gas to the pipe line. Leasing and drilling are largely between this area and Corydon, to the north.

There has been more leasing activity in southwestern Indiana in early 1934 than for many years. Considerable drilling is being done in areas where the structure has been worked out and some drilling in purely wildcat areas. Indications are that deeper drilling in some of the producing fields may be expected in the future.

Oil Development and Production of Kansas in 1933

By Marvin Lee,* Wichita, Kansas

(New York Meeting, February, 1934)

Kansas continued holding, for its seventh year, the fourth position in the list of oil-producing states. The crude-oil production, according to purchaser's reports to the State Corporation Commission, was 40,008,940 bbl.; as assembled by the *Oil and Gas Journal*, 41,305,768, and by the U. S. Bureau of Mines, 41,942,000 barrels.

Increase of production from 1932 was largely due to greater stability of the industry, and increased return of demand for Kansas oil, caused by the addition of Federal assistance in national production regulation which reduced illegal production, of some areas out of Kansas, that had been destructively competing with Kansas crude or its refined products, at less than cost of production.

Prices continued to advance from the lowest level of 25¢ per barrel during part of May and June, until by the end of September 36° gravity crude had reached $1 per barrel and continued at this price the remainder of the year. Price stability, for a period greater than in previous years, has brought renewed confidence to those producing oil and has led to renewed interest and increased purchases of Kansas leases.

Drilling was confined chiefly to the number of wells necessary to protect from offset and other drainage in the field and to meet the requirements of expiring lease contracts.

Drilling costs in Kansas being moderate, as compared to many of the deeper areas in Mid-Continent, are an added inducement to exploration. The renewal of interest in the search for new fields in Kansas is already apparent and 1934 will probably see more wildcatting than for several years. This is due both to the expiration of leases on large blocks and to actual demand of the industry for new fields.

Exploration for favorable areas is being actively conducted by the various methods of surface, subsurface and core drilling and geophysical work. Much of western Kansas cannot be mapped by surface study and geophysical exploration has been of considerable assistance and has led to a large use of the seismograph. Several companies are conducting seismograph surveys and leasing on findings already secured.

Development under the more favorable conditions of 1933 can be readily seen by the comparison of the following reports for the last weeks of December in the respective years.

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* Consulting Petroleum Geologist.

	1932	1933
Reported locations	31	46
Reported rigs	26	30
Wells drilling	62	98
Wells shut down for titles, etc	37	39
Wells shut down for casing	3	1
Wells shut down for completion	2	10
Total active operations in state	161	223

	1932	1933
Number of oil wells completed	10	6
Number of gas wells completed	1	
Number of dry holes completed	5	6
Number of abandoned rigs		1
Number of abandoned locations	3	1
Total	19	14

New discoveries in 1933 were less than normal, largely on account of general depression conditions and low prices until after the middle of the summer. Only five new areas removed from production and classed as new discoveries were the result of wildcatting in the year. These were Chase, Gates, Thode, McCann and Brandenstein pools. The principal information concerning these is given in Table 3. New discoveries were made in Ritz-Canton by development of a shallow gas pay at 664 ft. and a new discovery of a pool in sec. 8-20-1W. about 1½ miles southeast of Ritz-Canton, the latter production being the same depth as in the field, from the Viola lime.

Important extensions to Kansas fields, and rather rapid drilling, became the important action in fields previously being slowly developed and important extensions were especially noted in Raymond, Haury, Chindberg, Hollow and Nikkel areas of western Kansas. Most of the extensive development by drilling was in the western fields. The production and new drilling for the year are listed in Table 1.

Proration, as had been conducted under state law, was limited to fields not having 100 per cent outlet. The production from such pools was distributed to purchasers on the basis of their nomination to purchase and divided among producers in proportion to their ability to supply purchasers' nomination. This condition resulted in many fields having 100 per cent market, while others were without outlet for any production.

Proration, in cooperation with Federal Oil Administrator, has resolved into the fixing of an allowable each month for the state, since Sept. 8,

which has been as follows: September, 111,000 bbl. daily; October, 116,000; November, 116,000; December, 112,000.

The State Corporation Commission, through its Oil and Gas Conservation Division, supervised by the State Oil Umpire, allocates to the several pools of Kansas their proportionate part of the state market each month. Proration has been applied to all fields, having greater than 5-bbl. average. The allowable in percentage is greatest on the fields of smaller wells and smallest on the fields of large wells, based on the potentials taken under supervision of the Umpire. Practically all production in Kansas has pipe line connections. The seasonable demand for production in the summer of 1934 is expected to increase Kansas allowable considerably above the amount produced in December.

Acid treatment, to increase production, first began to be used early in 1933. Most of the fields of Kansas, especially in the western part of the state, have some lime producing horizon, or are producing wholly from limestone. The number of wells that have been treated with acid is not accurately known, but one chemical company probably treated 500 wells in 1933 and several others treated smaller numbers, and some acid treatment is being done by the producers. An estimate of 2000 acid treatments in 1933 is probably low. The results, from immediate increase of production in some lime formations, especially Kansas City-Lansing lime, series have been extremely satisfactory. Some difference of opinion is held as to the ultimate value of acid treatment on total recovery. Several wells that were not economically possible to operate have been profitably continued in practically all lime producing fields. New wells are frequently completed by acid treatment instead of by shooting, or by acid treatment following shooting.

Reports of production of all properties in the state are not obtainable, but Table 1 gives the potential at the end of the year, by fields.

Acknowledgments

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TABLE 1.—*Oil and Gas Production in Kansas*

Line Number	Field, *County*	Age, Years to End of 1933	Daily Average Potential, Dec., 1933 Total Oil Production in Barrels	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Dry and Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[c]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Producing Rock: Name as Locally Used	Producing Rock: Age[g]
1	Abbeyville, *Reno*	6.0	*x*	1	0			1			1	3,588		Lansing-Kansas City	Pen
2	Aldrich, *Ness*	5.0	*x*	1	0			1			1	4,430		?	
3	Atyeo-Pixlee, *Greenwood-Lyon*		381		0			70			70			Bartlesville sand	Pen
4	Augusta, North, *Butler*	17.0	1,128					112			112			?	
5	Augusta, South, *Butler*	17.0	1,328		1			148			148			?	
6	Benton, *Butler*	8.0	46					4			4		2,850	"Chat"	Mis
7	Beyer, *Rice*	3.0	875	5	2	1		5			5	3,250		Conglomerate-Sil. Ls	Pen, Cam-Ord
8	Brandenstein, *Rice*	0.1	1,083	1	1			1			1	3,026		Lansing-Kansas City	Pen
9	Breford, *Ellsworth*	1.3	1,149	4	3	1		4	?		4	3,230		"Siliceous" lime	Cam-Ord
10	Browning, *Greenwood*		924					121			121			Bartlesville sand	Pen
11	Burden, *Cowley*		437					22	?		22			Bartlesville sand	Pen
12	Burkett, *Greenwood*		1,090					319			319			Bartlesville sand	Pen
13	Burrton, *Reno*	2.6	4,068	29	15	1			29		29	3,350		Mississippi lime	Mis
14	Caldwell, *Sumner*		609	4	1			3			3	4,790		"Wilcox" sand	Ord
15	Carson, *Cowley*	8.3	290					22			22				
16	Chase, *Rice*	0.8	21,761[1]					28			28	3,250		"Siliceous" lime	Cam-Ord
17	Chindberg, *McPherson*	4.0		4	3				4		4	3,010		"Chat"	Mis
18	Churchill, *Sumner*	7.5	1,502	90				67			67			"Stalnaker" sand	
19	Clark, *Cowley*		50					4			4				
20	Climax, *Greenwood*	7.0	135					5			5		1,850	Mississippi lime	Mis
21	Coffey Misc., *Coffee*		41					8			8				
22	Cowley Misc., *Cowley*		310		3			43			43				
23	Covert-Sellers, *Marion*		414					23			23				
24	Cross, *Sedgwick*	4.7	7					1			1			Lansing-Kansas City	Pen
25	Cunningham, *Kingman*	3.0	4,685	13	6			13	?		13	3,450		Lansing-Kansas City	Pen
26	Davidson, *Barton*	3.8		1			1								
27	Denton, *Elk*		334		1						41				
28	DeMalorie-Souder, *Greenwood*		872		1						132			Bartlesville	Pen
29	Dillner, *Russell*	3.1		2			2						2,150		
30	Douglass, *Butler*		124		1						20				
31	East Kansas (Shallow), *Several*		7,254								11,322				
32	Eastborough, *Sedgwick*	4.3	1,959	56				46			46			Miss. Ls-Viola Ls	Mis, Ord
33	Eastman, *Cowley*		299								35			Bartlesville	Pen
34	Elbing, *Butler*		1,485								70			Silicious lime	Cam-Ord
35	Eldorado, *Butler*		13,693		1						1,701				
36	West Elk (Misc.), *Elk*		286		1						27				
37	Ellinwood, *Barton*	1.5	1,814	6	5	1					6	3,350		Siliceous lime	Cam-Ord
38	Eureka Townsite, *Greenwood*	7.5	65								15		1,900	Mississippi lime	Mis
39	Fairport, *Russell & Ellis*	10.1	6,649	139	1						116			Lansing-Kansas City	Pen
40	Fall City, *Cowley*		71								17			Kansas City	Pen
41	Fankhouser, *Greenwood*		206		1	1					80			Bartlesville sand	Pen
42	Florence-Urschell, *Marion*		177								17			Siliceous lime	Cam-Ord
43	Fox Bush, *Butler*		802								205			Bartlesville sand	Pen
44	Garden-Shaffer, *Butler*		1,132								79			*x*	
45	Gates, *Stafford*	0.5	153	1	1						1			Siliceous lime	Cam-Ord

46	Gideon, *Russell*	3.5	150	1							1			x	
47	Goodrich, *Sedgwick*	5.1	1,316	13							13			x	
48	Gorham, *Russell*	7.2	1,800	37	1	1					31			Penn Conglomerate	Pen
49	Graham, *Cowley*		162								15			Laton sand-Sil Ls	Pen, Cam-Ord
50	Greenwalt, *Rush*	2.3	8	1							1			x	
51	Greenwich, *Sedgwick*		6,842	61	9						36			x	
52	Greenwood Misc., *Greenwood*		53		1						30			x	
53	Halstead, *Harvey*		x133	5							2			"Chat" x	Mis
54	Hamilton, *Greenwood*		916		7	11					80			Bartlesville	Pen
55	Hanna, *Elk*		84								21			x	Pen
56	Haury, *Reno*	3.3	1,399	9	4						8			Miss "Chat"	Mis
57	Haverhill, *Butler*	7.0	472								65	2,700		Bartlesville	Pen
58	Hazlette, *Butler*		30								4			Miss "Chat"	Mis
59	Heiken, *Ellsworth*	3.2	275	4	2						4			x	
60	Hillsboro, *Marion*	5.2	537	17							12			x	
61	Hittle, *Cowley*		132								16			Kansas City lime	Pen
62	Hollow, *Harvey*	1.9	65,341	86	71	5					86			Miss "Chat," Hunton lime, "Wilcox". sand	Mis, Sil-Dev, Ord
63	Isern, *Barton*	2.1	1,296	3	1						3			x	
64	Johnson, *McPherson*	1.8	4,513	21	3	2					21			Mississippi "Chat"	Mis
65	Keighley, *Butler*	8.0	264								71			Bartlesville sand	Pen
66	Kramer, *Butler*	7.0	1,383								28			Viola? lime	Ord?
67	Kuske, *Sedgwick*	4.0	27	2							1			x	x
68	Laton, *Rooks*	7.0	52	4							2			x	x
69	Lamont, *Greenwood*	6.0	516		4	3					106	1,650		Bartlesville sand	Pen
70	Latta, *Sumner*	5.5	301	9							7			Lansing-Kansas City	Pen
71	Leon, *Butler*		102								27			Bartlesville sand	Pen
72	Lost Sprgs, *Marion*	7.0	371								48			Miss. "Chat"	Mis
73	Madison, *Greenwood*		894	3							104			Bartlesville sand	Pen
74	McCarty, *Edwards*	3.8	45	3							2			x	
75	McCann, *Butler*	0.3		1							1			Miss. "Chat"	Mis
76	McPherson, *McPherson*	4.5	89	9							6			Miss. "Chat"	Mis
77	Miller, *Russell*	1.7	150	2							2			x	
78	Moline Townsite, *Elk*		151								29			x	
79	Nikkel, *Harvey, McPherson*	1.2	28,448	32	23	1					32			Miss. "Chat," Hunton lime	Mis, Sil-Dev
80	Ochs, *Russell*	3.2	282	3	1						3			x	
81	Orth, *Rice*	1.5	975	4	3	2					4			x	
82	Otis, *Rush*										2[2]			■	
83	Oxford, *Sumner*	5.7	1,089	107							63			Stalnaker sand	Pen
84	Oxford West, *Sumner*	6.6	78	6							4			"Siliceous" lime	Cam-Ord
85	Padgette, *Sumner*	8.2	479	23							21			x	
86	Peabody, *Marion*	14.0	331								41			x	
87	Ploog, *Rice*	2.4	637	1							1			x	
88	Potwin, *Butler*		994								38			x	
89	Quincy, *Woodson, Greenwood*	7.0	435		10	2					49	1,450		Bartlesville sand	Pen
90	Rainbow Bend, *Cowley*	10.0	1,221								118	3,225		Bartlesville sand	Pen
91	Rainbow West, *Sumner*	7.8		12							8			x	
92	Raymond, *Rice*	3.4	12,009	17	6						17			x	
93	Reece, *Greenwood*		152								17			Mississippi lime	Mis
94	Rega, *Trego*	3.7		1			1							x	
95	Richardson, *Stafford*	2.3	4,150	6	2						6			Siliceous lime	Cam-Ord

[c] Footnotes to column headings and explanation of symbols are on page 175.
[1] Total oil production to end of 1933 was 610,408 barrels.
[2] Total gas production to end of 1933 was 3,000,000 cubic feet.

TABLE 1.—(*Continued*)

Line Number	Field, *County*	Age, Years to End of 1933	Total Oil Production, Bbl. Daily Average Potential, Dec., 1933	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Dry and Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[a]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Producing Rock: Name as Locally Used	Producing Rock: Age[a]
96	Ritz-Canton, *McPherson*	3.5	36,140	243	54	4					219			Miss. "Chat," Viola lime, "Wilcox" sand	Mis, Ord
97	Robbins, *Sedgwick*		1,061	9							9			Mississippi lime	Mis
98	Rock, *Cowley*		85								17			Bartlesville sand	Pen
99	Sallyards, *Butler, Greenwood*		938								242			Bartlesville sand	Pen
100	Scott, *Greenwood*		347								65			Bartelsville sand	Pen
101	Seeley, *Greenwood*		1,803		10	1					326	1,850		Bartelsville sand	Pen
102	Sellens, *Russell*	3.6	958	9							9			*x*	
103	Severy, *Greenwood*		20								9			*x*	
104	Sharpe, *Rice*	1.8	3,343	4		1					4				
105	Shutts, *Ellis*	4.0	627	10		1					10				
106	Smith, *Cowley*		96								13			Bartlesville	Pen
107	Smock-Sluss, *Butler*		286								53			Bartlesville	Pen
108	State, *Cowley*		424								23			"Siliceous" lime	Cam-Ord
109	Steckel, *Rice*	1.1	148	1							1				
110	Stoltenberg, *Ellsworth*	2.5	11,960	13	6	1					13				
111	Stratmann, *Ellsworth*	2.8	4,447	16	6						16				
112	Sumner Misc., *Sumner*		28								3				
113	Teter, *Greenwood*		1,062		1						225			Bartlesville sand	Pen
114	Thode, *Rice*	0.3	297	1	1						1			Miss. "Chat"	Mis
115	Thrall, *Greenwood*		216		1						86			Bartlesville	Pen
116	Valley Center, *Sedgwick*	4.4	2,933	127	1						64			Simpson dolomite	Ord
117	Vernon North, *Sumner*			3		1					1			*x*	
118	Virgil, *Greenwood*		499		8	2					127			Bartlesville sand, Mississippi lime	Pen, Mis
119	Voshell, *McPherson*	3.4	18,366	139	8	5					118			Miss. "Chat," Sil lime, Viola lime, Misener sand, "Wilcox" sand	Mis, Ord, Cam-Ord
120	Walton, *Harvey*	10.0		10							1			Kansas City lime	Pen
121	Weaver, *Butler*		27								10			Bartlesville sand	Pen
122	Webb, *Elk*		324								89			"Oswego" lime	Pen
123	Welch, *Rice*	9.0	1,350	32	3	1					26			"Chat"	Mis?
124	Wellington, *Sumner*	4.0	288	4							4			Mis "Chat"	Mis
125	Wilkerson, *Greenwood*		1,787		5	1					392			Bartlesville	Pen
126	Winfield, East, *Cowley*		902	*x*	3						93			*x*	Pen
127	Winfield Tst., *Cowley*		1,698		10						54			Layton sand, Siliceous lime	Pen, Cam-Ord
128	Winterscheid, *Woodson*		872		2						184			*x*	*x*
129	Woodson Misc., *Woodson*		31	*x*	4						8			*x*	*x*
130	Wiggins, *Greenwood*		250								66			*x*	*x*
131	Young, *Butler*		216								17			Kansas City lime	Pen
132	Yocemento, *Ellis*			4							2			*x*	*x*
138	Total		314,601		319	50					18,894				

[a] Footnotes to column headings and explanation of symbols are on page 175.

TABLE 2.—*Summary of Drilling Operations in Kansas*, 1933

(Figures in body of tabulation represent number of holes.)

County	Completed during 1933							Productive Gas Wells (For Details See Table 1)
	Dry and/or Near-dry Holes						Productive Oil Wells (For Details See Table 1)	
	Total Depths, Ft.					Total		
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000			
Barton	0	0	0	4	0	4	8	0
Butler	1	0	0	3[2]	0	4	3	0
Chase	0	0	2	0	0	2	2	0
Coffey[1]								
Cowley	0	1	1	6	0	8	12[2]	5[2]
Dickinson	0	0	0	0	1[2]	1	0	0
Douglas	0	1	0	0	0	1	0	0
Elk	0	5	2[2]	0	0	8	4[2]	0
Ellis	0	0	0	1	0	1	3[2]	0
Ellsworth	0	0	0	6	0	6	15	0
Geary	1	0	0	0	0	1		0
Graham	0	0	0	0	1	1		0
Greenwood	0	25	17	0	0	42	48[4]	1
Harvey	0	0	0	12	0	12	82[4]	0
Kingman	0	1	1	0	1	3	6	0
Lyon	0	0	1	0	0	1	0	0
Marion	0	0	2	1	0	3	0	0
McPherson	0	3	21[3]	0	0	24	120[5]	9[2]
Morris	0	0	0	0	0	0	0	1
Ness	0	0	0	1	0	1	0	0
Osage	0	0	1[3]	0	0	1	0	0
Pratt	0	0	0	0	1	1	0	0
Reno	0	0	0	5	0	5	11	5
Rice	0	0	0	6	0	6	47[2]	0
Rush	0	0	0	1	0	1	0	2
Russell	0	0	0	1	0	1	46[2]	0
Saline	0	0	0	2	0	2	0	0
	0	0	0		0			
Sedgwick	0	0	0	4[2]	0	4	10	0
Stafford	0	0	0	0	0	0	3	0
Sumner	0	0	1	1	0	2	1	0
Woodson	0	10	0	0	0	10	16	0
Total						156	395	23

	WELLS
Total old wells deepened	56
Total new completions	518
Total activity	574

[1] One oil well in 1933.
[2] Of this number, one was an old well deepened.
[3] Of this number, three were old wells deepened.
[4] Of this number, two were old wells deepened.
[5] Of this number, 37 were old wells deepened.

TABLE 3.—*New Pool Discoveries in Kansas*, 1933

Pool	Location	County	Date Discovered	Discovered by	Lease Name	Status of Field Dec. 31, 1933		Initial Production	Local Name of Producing Horizon (Geologic Age)	Total Depth of Well, Ft.
						Wells	Production to End of Yr.			
Chase	NW. SW. NW. S.32-T.19-R.9-W	Rice	Jan. 5	Ramsey Pet. Co.	School No. 1	28	610,408	14 bbl. per hour	"Siliceous lime" (Cam-Ord)	3,289
Gates	NE. SW. S.27-T.21 R.13W.	Stafford	May 14	Atlantic Oil Producing Co.	Gates	1	Producing	100 bbl. per day	"Siliceous lime" (Cam-Ord)	3,714
Ritz-Canton	NW. NE. S.23-T.19 R.2W.	McPherson	June 28	Helmerick and Payne	Russell	1	Shallow gas pay in field	150,000 cu. ft.	Limestone (Per)	664
Raymond	SE. SW. SW. S.16-T.20 R.10W.	Rice	Aug. 26	Tom Palmer	Specht	1	Pumping	410 bbl. in 18 hr.	Kansas City-Lansing (Pen)	3,140
Thode	C. NW. NW. S.11-T.21 R.7W.	Rice	Sept. 1	R. E. Garden and Son et al.	Thode	1	Producing	20 bbl. per hour	"Chat" (Mis)	3,380
McCann	SE. SW. NW. S.7-T.25 R.3E.	Butler	Sept. 20	Hartman Oil Corp.-Shell et al.	McCann	1	Producing	50 bbl.	"Chat" (Mis)	3,236
Brandenstein	SE. SE. S.10-T.19 R.10W.	Rice	Nov. 25	Atlantic Oil Producing Co.	Brandenstein	1	Producing	1,093 bbl.	Kansas City-Lansing (Pen)	3,026
Voght. 1½ mi. SE of (Ritz-Canton Area)	C. SE. SE. S.8-T.20 R.1W.	McPherson	Nov. 29	Regina Oil Co.	Voght	1	Pumping	541 bbl.	Viola lime (Ord)	3,398

Oil and Gas Production in Kentucky, Ohio, and West Virginia

By Veleair C. Smith,* Charleston, W. Va.

(New York Meeting, February, 1934)

Reliable and detailed statistical data available for Kentucky, Ohio and West Virginia are the most meager and unsatisfactory of any of the producing states. Detailed histories and statistics are available for only a few pools.

The antiquity of these pools, loose nomenclature, particularly where several names are applied to the same pool or various parts of the pool or a new name used when the pool was rediscovered, made the collection of accurate historical and statistical data almost impossible. So many of the data reported are unreliable that a breakdown by pools or even by counties, until more accurate information is available, would lead to gross errors. Rather than perpetuate inaccuracies, we have endeavored to go to original sources wherever possible, sift these and provide data that may serve as an incentive and basis for future work. The necessity for accurate information is thoroughly recognized by the operators, particularly because of the effect of recent government regulations and requests for data in connection with the preparation of the various codes and pending legislation.

Producers, both major operating companies and individuals, have freely given their time and assistance in the compilation of these data. Valuable information was obtained from tax records, rate cases, statistics published by the oil and gas publications and the Bureau of Mines. So many individuals cooperated in the preparation of these data that individual credit cannot be given. Undoubtedly many errors will be found. Some of the data are open to controversy, and many have been omitted in the hope that new information of a more reliable character may become available. Other omissions are due to an inability to contact the proper individuals, many of whom are no longer connected with this industry.

Pennsylvania grade crude sold in 1933 for the lowest price since 1895. Gas production could not find sufficient new markets to fill the void left by industrial stagnation. In the gas industry, where the market price is fixed by contract, uncertainty persisted because of impending legislative action affecting both taxes and utility rates. As a result of these factors and a lack of new money, drilling was restricted to a new low. The lifting of proration toward the end of the year in the Pennsylvania

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area, and possible local shortage of Pennsylvania crude, should result in renewed activity in 1934.

Many properties and wells operated on a narrow margin had to be abandoned, owing to the necessity for curtailing operating expenses. As a result there has been a large loss in reserves. In many cases this will be permanent because the size of the wells and the investment required will prevent new drilling.

Kentucky

Oil was first discovered in Kentucky about 1819. The production history of this state is long and varied. The western fields are notable because of the shallow production and low initial investment required. This has resulted in emphasizing wildcat operations without considerable field work in advance of drilling, owing not only to the number of small operators but also to the disproportionate cost between necessary field work, drilling costs and the irregular character of the production. The percentage of dry holes drilled is probably the largest in any part of the United States. Three-fourths of the State of Kentucky has either produced oil or gas or may be classed as prospective territory. Low cost of operations frequently carried on by local capital makes accurate information and statistics unobtainable.

The Kentucky Survey has frequently used tax records in analyzing some of these operations, but unfortunately these are not available for 1933 at this time.

The year was one of greatly curtailed operations, reflecting general underconsumption, particularly in the gas fields, which were affected by both mild weather and restricted markets in the eastern and northern areas. In spite of this a considerable amount of drilling was carried on in Pike, Floyd, Martin and Knox counties, where some 128 wells were drilled. Part of this drilling was obligatory and most of it with the object of developing the Devonian (Brown) shale. Two deep test wells were drilled in Pike County and Letcher area, both exceeding 4000 ft. Two of the oil companies operating in the eastern area expanded their repressuring operations with profitable results. Undoubtedly this, with increased demand for crude, will further stimulate repressuring and also new operations.

In western Kentucky two good oil wells were drilled in the Barrett Hill section of Ohio County.

An interesting development was the drilling of a well adjacent to the Emerson and Stockton well, drilled in 1829. This well encountered production at 400 ft. Ohio and Daviess counties were the most active in the western area. However, current reports indicate increased activity as soon as weather conditions permit and should result in considerable activity in the old proven areas of western Kentucky and also in wildcats drilled primarily for gas in the Blue Grass area.

More attention probably will be paid to the Kentucky area during the coming year than to either Ohio or West Virginia, because lease obligations will require the testing of certain areas, irrespective of marketing conditions, if leases are to be retained.

Ohio

Ohio's petroleum history presents a strange picture of oil fields discovered, developed, abandoned, often forgotten and rediscovered. The antiquity of the production, loose nomenclature and application of the term "field" or "pool" without any definite meaning or restriction has made it impossible to gather statistical material suitable for the Institute's form and of general value. The same problems that have confronted us in our efforts to gather accurate data have presented great difficulties in Ohio. The release of such detailed data as we have could only lead to confusion and erroneous conclusions. The enormous number of wells drilled and long historical production, a part of which has never been recorded, leaves a gap that is hard to fill.

In 1933 one notable change occurred. In the old Trenton fields, the operators, refiners and pipe line companies joined forces in an effort not only to balance production to requirements but also to increase the local markets for their products, through mutual cooperation. This spirit undoubtedly will be extended to further cement the good relations and mutual helpfulness that has helped pull the industry in this area through a most critical period.

The largest well drilled was a 300-bbl. initial producer, in Wyandot County, in what is known as the Upper Sandusky field. A number of very good producing wells were drilled in this county. Production is from the Trenton and shows the usual trend of development, which seems to have been a result of continued water drive, and restores fields, long known, to new life and activity. Recently several good producers were drilled in Van Wert County as a result of the same condition and considerable acreage has been leased.

In Central Ohio, in the old Clinton field, Stark County leads in new work for both oil and gas and some good wells were drilled. Belmont and Muskingum have also been active.

In Southeastern Ohio drilling has continued with favorable results in the Devonian shale. As a result of the decline in old fields and the expectation of improved markets, these operations should expand during the coming year.

Our ideas about the shale have been somewhat changed and revised during the year. The absolute necessity for protecting the well against moisture, which will result in caving, improved shooting methods and the effect that structural control exerts upon production will stimulate both geological work and new drilling.

In Washington County, Ohio, Bendum and Trees drilled what is said to be the deepest test in Ohio. The exact depth of this well has been variously reported to the writer at 7767 ft. and 7890 ft. It was drilled to the White Medina through the Clinton. Production was not encountered and the well was pulled and plugged.

West Virginia

The outstanding event during the year in West Virginia was the development of the Lost Run Pool in Ritchie County, where one well produced over 5000 bbl. of oil in a five-day test. This is a narrow shoestring pool in the Injun sand, in an area of old production and has shown remarkable staying power. The present production is about 2000 bbl. per day. Pools of this character are of frequent occurrence in this state and present few, if any, novel features. Some extension of the present producing area may be expected of the wells now drilling to the south.

In the Huntington area development of the Brown shale slowed down somewhat, due in part to restrictions by the city.

Stimulated by renewed demand for crude, repressuring operations will be extended in several areas and experiments are now being carried on in both the lime and sandstone with acid treatment.

The tax situation and legislative uncertainty has been particularly bad in West Virginia, resulting in the abandonment of many operations and a policy of delay until something definite develops, or in development in areas where less uncertainty existed.

In summing up the situation in Ohio, Kentucky and West Virginia, operators who had sufficient funds were marking time, waiting to see what conditions would bring forth.

The huge surplus of salvaged materials prevented the application of new methods or improvements because of their low cost and availability. The low price of oil and the restricted market for gas gave no incentive to further development. Many old wells are showing serious water encroachment. Pumping of water from gas wells is proving profitable in many cases, and seems to be preferable to siphoning because it does not use up gas energy or result in as much waste.

Chemical utilization of gas as a raw material made no outstanding advance during the year. At the same time old fields continued to be drawn upon. Reserves were depleted and the major competitive fuel (coal) rapidly increased in price toward the end of the year. In the early part of the year there was a definite trend or shift from gas to coal, caused by the fixed price of gas and its comparatively high cost on a thermal basis. This trend has been reversed and events now in progress are emphasizing this change. Deeper sands are known to be productive and as soon as reasonable expectation of profit from such operations can be had, new work will rapidly increase.

TABLE 1.—*Oil and Gas Production in Kentucky, Ohio and West Virginia*

Field, *County* Kentucky	Age, Years to End of 1933	Average Depth, Ft. To Top of Productive Zone	Producing Rock Name	Producing Rock Age[a]	Character[a]	Net Thickness, Average Ft.	Structure[a]
KENTUCKY							
Little Rich. Ck., *Knox*	93–66	325±	Jones	Pen	S	45±	T
Rock Haven, *Meade*	75–32	671–2,132±	Lime, shale	Dev			TF
Cruesboro, *Russell*	72	590–1,135±	Sunnybrook, Trenton	Ord			A
Meade County, *Meade*	70	175±	Lime, shale	Dev			TF
Long Falls Ck., *McLean*	68	180±	Sebree Ss, Jett, Beech Grove	Mis, Dev			
Oskamp, *Barren*	68	5–900±	Lime	Dev			
Bakerton, *Cumberland*	67		Lime, Trenton	Ord			
Sewell, *Cumberland*	67–30		Lime, Trenton	Ord			
Irvine, *Estill*	55	190–900±–1,844	Lime, shale	Dev, Sil			A
Boyd County, *Boyd*	53	2,000±	Big Injun, Berea	Mis, Dev			
Montgomery Co., *Montgomery*	50		Eden	Ord			F
Cloverport, *Breckenbridge*	46	872±–887–1,225	Cloverport G. sand Cornif. lime	Mis, Dev			S
Emery, *Barren*	46		Shale	Dev			T
Boyd's Creek, *Barren*	45	116±–225	Shale	Dev			T
Glasgow, *Barren*	44	175–230±	Limestone	Dev, Sil, Ord			T
Bourbon County, *Bourbon*	45	200±	Trenton	Ord			TS
Oil City, *Barren*	44	350±	Limestone	Dev			
Somerset, *Pulaski*	44		Pottsville	Pen, Mis, Dev, Sil			
Steffy, *Barren*	44		Lime?	Dev			TS
Gas Hollow, *Barren*	43		Lime?	Dev			TS
Litchfield, *Grayson*	33–16	961–1,514±	Sil. lime, lime	Mis, Dev			F
West Point, *Hardin*	43–39		Lime (Cal.)	L. Ord			
Beaver Creek, *Floyd*	41		Salt, Max., Big Lime, Inj. shale				
Slickford, *Wayne*	41		Waverly, Trenton	Mis, Ord			AM
Cooper, *Wayne*	38	870±	Waverly, Trenton	Mis, Ord			AM
Sinking Creek, *Knox*	37	440±	Sand	Pen	S	30±	S
Oil Valley, *Wayne*	36		Waverly, Trenton	Mis, Ord			AM
Burning Springs, *Clay*	35		Cornif. lime	Den			A
LinCooper, *Wayne*	33		Waverly, Trenton	Ord			AM
Darnell, *Wayne*	33		Waverly, Trenton	Mis, Ord			AM
Ragland, *Bath*	33		Ragland, Niagara	Sil			A
Barbourville, *Knox*	32–31	470±	Sand	Pen	S	50±	A, S
Ellington, *Cumberland*	32		Trenton lime	Ord			
Knox County, *Knox*	32		Big Lime, Big Injun, Pottsville, Max.	Mis, Pen			
Menifee, *Menifee*	32		Cornif. lime, shale	Mis, Dev			
Ravenna, *Estill*	32		Lime shale	Sil			
Sunnybrook, *Wayne*	32		Waverly, Trenton	Mis, Ord		*y*	
Clover Creek, *Cumberland*	31		Waverly? Trenton	Ord		*y*	
Dry Fork, *Wayne*	31		Waverly? Trenton	Mis, Ord		*y*	
Parmleysville, *Wayne*	31		Waverly? Trenton	Mis, Ord		*y*	
Wildwood, *Allen*	31	100±–150±	Maxton Dev shale	Mis, Dev		*y*	A
Williamsburg, *Whitley*	31		Pottsville sands, Big Lime	Dev, Sil		*y*	A
Aratt, *Cumberland*	30		Trenton lime	Ord			
Bear Creek, *Cumberland*	30–13±		Trenton lime	Ord			
Compton, *Wolfe*	30		Lime, Niagara	Dev, Sil			FA
Fallsburg, *Lawrence*	30	1,700±	Pottsville, Weir-Berea	Dev, Mis			FS
Heard, *Cumberland*	30		Trenton	Ord			
Irish Bottom, *Cumberland*	30		Trenton	Ord			
Small, *Cumberland*	30	1,070±–3,517±	Salt, Max. Big Injun, shale	Pen, Dev			
Steubenville, *Wayne*	30		Waverly, Trenton	Ord			
Menifee, *Menifee*	29	1,200± ?	Lime, Cornif. shale	Dev			A
Morgan	28	1,200±	Big Lime, Big Injun, Weir, Berea	Mis, Dev			
Barrier, *Wayne*	28		Waverly, Trenton	Ord			
Dry Creek, *Knott*	28		Maxton, shale	Dev		460*y*	AS
Stinking Creek, *Wayne*	28		Waverly, Trenton	Mis, Dev			
Turkey Rock, *Wayne*	28		Waverly, Trenton	Mis, Dev			
Broadway?, *Floyd*	27		Salt Sand Injun, Max., Big Lime, shale	Pen, Dev			
Corder, *McCreary*	27	1,000±	Beaver	Mis			
Sulphur Creek, *Cumberland*	27		Trenton lime	Ord			
Bratcher Hal, *Wayne*	26		Waverly, Trenton	Mis, Ord			AM
Johnson Fork, *Wayne*	25		Waverly, Trenton	Mis, Ord			AM

[a] Footnotes to column headings and explanation of symbols are on page 175.

TABLE 1.—(*Continued*)

Field, *County* Kentucky	Age, Years to End of 1933	Average Depth, Ft.	Producing Rock				
		To Top of Productive Zone	Name	Age[g]	Character[h]	Net Thickness, Average Ft.	Structure[f]
Monticello, *Wayne*	25	2,450±	Waverly, Trenton	Mis, Ord			
Mt. Pisgah, *Wayne*	25		Waverly, Trenton	Mis, Ord			
Rocky Branch, *Wayne*	24		Waverly, Trenton	Mis, Ord			
Stillwater, *Wolfe*	24		Lime, Niagara	Dev, Sil			FA
Beach Grove, *McLean*	23	400±	Beech Grove, Sebree	Pen			
Diamond Spring, *Logan*	23	1,300±	Shallow gas lime, shale	Mis, Dev, Sil			
Central City, *Muhlenberg*	23	100±	Chester	Mis			
Gibson, *Wayne*	23		Waverly, Trenton	Mis, Ord			AM
Patton, *Wayne*	23		Waverly, Trenton	Ord			AM
Cannel City, *Morgan*	21		Big Injun, Big Lime, Berea	Mis, Dev, Sil			
Hartford, *Ohio*	21	500±-700±	Jetts. lime	Mis, Dev			
Petroleum, *Allen*	21	125±	Shale, Trenton lime	Dev, Sil			
Rodemer, *Allen*	21	220±	Lime	Dev			
Big Hill, *Madison*	17	120±	Shale, lime	Dev, Sil			
Bolyn, *Knott*	17		Maxton? Shale	Mis, Dev			
Gainesville, *Allen*	17	350±	Trenton	Sil? Dev			
Hiserville, *Barren*	17		Trenton	Dev			TF
Ashley, *Powell*	16	500±	Onondaga lime shale	Dev, Sil			FA
Brush Creek, *Floyd*	16						
Bull Creek, *Floyd*	16						
Emberton, *Monroe*	16	2,000±	Sunnybrook	Ord			
Flat Gap, *Johnson*	16	1,110±	Big Injun, Weir-Berea	Mis			F
Caddie, *Metcalf*	16		Waverly	Mis			
Green River, *Greene*	16		Niagara	Dev, Sil			
Holly Creek, *Wolfe*	16		Cornif. lime, Trenton	Dev, Sil			
Jackson, *Warren*	16		Onondaga	Sil			A
Lanhart, *Jackson*	16	1,400±	Unnamed sands, Cornif. lime	Mis, Dev			
Meredith, *Grayson*	16	940±-1,800±	Lime	Mis, Dev			
Newcombe Cr., *Elliot*	16	700±-2,000±	Weir-Berea	Mis, Dev			FA
Olympia Cr., *Bath*	16	900±	Niagara, Olympia	Sil			A
Paint Creek, *Johnson*	16	1,100±	Big Injun, Weir-Berea	Mis			F
Tobey, *Metcalf*	16		Waverly	Mis			
Williams, *Warren*	16		Onondaga	Sil			
Big Stinking Cr., *Lee*	15	1,100±-1,200±	Cornif., Niagara	Dev, Sil			S
Denton, *Carter*	15	700±	Pottsville, Weir-Berea	Pen, Mis			
Frozen Cr., *Breathett*	15		Pottsville, Weir, Cornif., Niagara, U. Ord	Pen, Mis, Sil, Dev-Ord			
Cott, *Warren*	15		Onondaga, lime	Sil			
Green River, *Lincoln*	15	350±	Shallow sand Cornif. 2d sand	Mis, Pen Dev			
Hunt, *Allen*	15		Lime	Dev, Sil			
Lineman, *Lee*	15		Shale, lime	Sil			
Little Frozen, *Breathett*	15	1,600±	Pottsville, Weir, Cornif. Niagara	Pen, Mis, Dev, Sil Ord			
Mariba, *Menifee*	15	1,200±	Cornif., shale	Dev, Sil			
Meador, *Allen*	15						
Prestonburg, *Floyd*	15		Lime, shale	Dev, Sil			
Red Bush, *Lawrence*	15		Pottsville, Weir-Berea	Pen, Mis			FA
Red River, *Powell*	15	700±	Lime, shale	Dev, Sil			FA
Sam Martin, *Warren*	15	1,100±	Cornif., Niagara	Dev, Sil			
Scottsville, *Allen*	15	272±	Cornif.	Dev			
Short Creek, *Grayson*	15		Shale	Sil			F
Sledge, *Allen*	15	350±	Trenton	Dev			
Stanton, *Powell*	15	250±	Lime shale	Dev, Sil			FA
Travelers Rest, *Owsley*	15	1,500±	Cornif.	Dev			
Wenn, *Johnson*	15	1,100±	Big Injun, Weir-Berea	Mis			F
Beech Bottom, *Clinton*	14	800± 2,000±	Beaver, Trenton, Beech Bottom	Mis, Ord, Cam, Ord			
Davenport, *Clinton*	14		Beaver, Trenton, Beech Bottom	Mis, Ord, Cam, Ord			
Flat Rock, *Simpson*	14			Mis, Ord			
Hawesville, *Hancock*	14		Chester, shale	Mis, Dev			
Ivyton, *Magoffin*	14		Pottsville, Max., Big Lime, Weir	Pen, Mis			
Johnson, *Allen*	14		Cornif., shale	Dev, Sil			
Louisa, *Lawrence*	14		Pottsville, Weir-Berea	Pen, Mis			FS
Moulder, *Warren*	14	450±	Lime	Dev			
Mt. Areial, *Allen*	14		Waverly, Trenton	Mis, Ord			

[g] Footnotes to column headings and explanation of symbols are on page 175.

TABLE 1.—(*Continued*)

Field, *County* Kentucky and Ohio	Age, Years to End of 1933	Average Depth, Ft. To Top of Productive Zone	Producing Rock Name	Producing Rock Age[g]	Producing Rock Character[h]	Producing Rock Net Thickness, Average Ft.	Structure[j]
Neals Creek, *Lincoln*	14		Shallow gas sand Cornif. 2d sand	Pen, Dev			
Rousseau, *Barren*	14	1,500–2,000±	Lime?	Dev			TF
Spencer Hiems, *Wolfe*	14		Lime, Niagara	Dev, Sil			TA
Steele Creek, *Floyd*	14		Shale, lime	Sil, Dev			
Stringer, *Simpson*	14						
Sturgen Creek, *Lee*	14		Cornif., Niagara	Dev, Sil			
Susie, *Wayne*	14		Waverly, Trenton	Mis, Ord			
Wheat, *Allen*	14	135– 250±	Lime, Niagara	Dev, Sil			
Alonzo, *Allen*	13		Cornif. lime, shale	Dev, Sil			
Bolt's Fork, *Boyd*	13		Big Injun, Berea	Mis, Dev			
Coops, *Cumberland*	13		Trenton	Ord			
Fugate, *Johnson*	13	1,100±	Big Injun, Weir-Berea	Mis			F
Keaton, *Johnson*	13	1,100±	Big Injun, Weir-Berea	Mis			F
Keen, *Allen*	13	1,100±	Maxton, shale	Mis, Dev			
Mitchell, *Warren*	13		Cornif., Niagara	Dev, Sil			
Oil Branch, *Johnson*	13		Big Injun, Weir-Berea	Mis			F
Olmstead, *Logan*	13	1,300±	Shallow gas sand, lime shale	Mis, Dev, Sil			
Oneida, *Clay*	13	1,200±	Cornif. lime	Dev			A
Pelville, *Hancock*	13		Chester, shale	Mis, Dev			
Pilot Knob, *Simpson*	13						
Walbridge, *Lawrence*	13		Pottsville, Weir-Berea	Pen, Mis			FS
Pike Co., *Pike*	*y*		Shale	Dev			
Martin Co., *Martin*	*y*		Shale	Dev			
Windy City, *Wayne*	13		Waverly, Trenton	Mis, Ord			AM
Bealcher, *Warren*	12	1,100±	Cornif., Niagara	Dev, Sil			
Calvary, *Allen*	12		Maxton, shale	Mis, Dev			
Grin, *Rowan*	12	450±	Ragland, Cornif., Niagara	Dev, Sil			
Peart, *Logan*	12		Shallow gas sand, lime shale	Mis, Dev, Sil			
Penrod, *Muhlenberg*	12	1,000±	Chester	Mis			
Powell, *Logan*		1,300±	Shallow gas sand, lime shale	Mis, Dev, Sil			
Pugh, *Simpson*	12						
Reeder, *Simpson*	12						
Rochester, *Butler*	12	1,800±	Unnamed lime, shale	Mis, Dev, Sil			
Sandige, *Warren*	12	1,100±	Cornif., Niagara	Dev, Sil			
Satterfield, *Allen*	12		Maxton	Mis, Dev			
Simmons, *Warren*	12		Cornif., Niagara	Dev, Sil			
Slanks, *Warren*	12		Cornif., Niagara	Dev, Sil			
Vance Potter, *Warren*	12		Cornif., Niagara	Dev, Sil			
Weaver, *Warren*	12		Cornif., Niagara	Dev, Sil			
Cable, *Wolfe*	11		Niagara	Sil			
Dyson, *Allen*	11		Maxton	Dev			
Morton's Gap, *Hopkins*	11	350±	Unnamed	Pen, Mis			
Penner, *Warren*	11	1,100±	Cornif., Niagara	Dev, Sil			
Pine Ridge, *Wolfe*	11		Niagara	Dev, Sil			FA
Rocky Hill, *Warren*	11	1,100±	Cornif., Niagara	Dev, Sil			
Ida May, *Owsley*	10		Cornif.	Dev			
Buffalo Creek, *Owsley*	9		Cornif.	Dev			
Island Creek, *Owsley*	9		Cornif.	Dev			
Crocus Creek, *Cumberland*	9		Trenton	Ord			
Kettle Creek, *Monroe*	9	2,000±	Sunnybrook	Ord			
Proctor, *Union*	8	637±	Sebree sands	Pen			
Pulsey Creek, *Cumberland*	8		Trenton	Ord			
Ambrose, *Ohio*	7	500±	Jett	Mis, Dev			
		700±					
Hayden, *Daviess*	6	700±	Pottsville	Pen			
King, *Daviess*	6	700±	Unnamed	Mis			
Ruby, *Daviess*	6	700±	Pottsville	Pen			
			Unnamed	Mis			
Whitesville, *Daviess*	6	700±	Pottsville	Pen			
			Unnamed	Mis			
Brown, *McLean*	6		Sebree, Jett	Pen, Mis			
OHIO							
Beldon, *Lorain*	73	2,450±	Clinton? Berea	Sil, Mis		*y*	
Mecca, *Trumbull*	73	1,100–60	Berea	Mis		*y*	
Williamsport, *Columbiana*	68		Berea			45*y*	
Frozeyburg, *Coshocton*	68		Berea	Mis		*y*	
Mahoning	67						
Geneva, *Ashtabula*	53±						
Blabensburg, *Knox*	48						

[g] Footnotes to column headings and explanation of symbols are on page 175

TABLE 1.—(*Continued*)

Field, *County* Ohio	Age, Years to End of 1933	Average Depth Ft. To Top of Productive Zone	Producing Rock Name	Producing Rock Age[a]	Character[a]	Net Thickness, Average Ft.	Structure[a]
Mt. Vernon, *Knox*	48						
Stark	48	650	Berea, Clinton	Mis, Sil			
Thurston, *Fairfield*	45	515±-2,400±	Berea, Clinton	Mis, Sil		*y*	
Barnesville, *Belmont*	44	960±-2,000±	Maxton, Berea	Mis		*y*	
Cadiz, *Harrison*	44		Berea	Mis			
Island Creek, *Jefferson*	44	1,000	Berea	Mis		30	
Toronto, *Jefferson*	42		Berea	Mis			
Colerain, *Belmont*	39	960±-2,000±	Maxton, Berea?	Mis			
Jewett, *Harrison*	38						
Gould, *Jefferson*	38	1,200	Berea	Mis		33	
Knoxville, *Jefferson*	37		Berea	Mis		50	A, S
Scio, *Harrison*	38	1,190	Berea	Mis		45	
Temperanceville, *Belmont*	34	1,600-2,000±	Berea?	Mis		*y*	
Wellsville, *Columbiana*	34		Berea	Mis			
Vaggi, *Columbiana*	34		Berea	Mis			
Philadelphia Rd., *Harrison*	34		Berea	Mis		25	
Bowerstown, *Harrison*	34		Berea	Mis			
Bricher, *Harrison*	34		Berea	Mis			
Maxwell, *Harrison*	34		Berea	Mis			
Lodi, *Medina*	34	450?±	Berea?	Mis		*y*	
Amsterdam, *Carroll*	33		Berea	Mis			
Homeworth, *Columbiana*	33	618	Berea?	Mis		35	
Snyder, *Harrison*	33		Berea	Mis			
Port Homer, *Jefferson*	33	615	Berea	Mis			
Plumb Run, *Harrison*	31		Berea	Mis			
Bluck, *Jefferson*	28		Berea	Mis			
Cleveland, *Cuyahoga*	21	710±-3,000±	Clinton? Berea	Sil, Mis		*y*	
Berea, *Cuyahoga*	19		Berea	Mis			
		710±	Berea	Mis		*y*	
Buck Run, *Morgan*	73	82	Cow Run				
Chester Hill, *Morgan*	73	80	Cow Run				
Macksburg, *Washington*	73		Cow Run, Warren, Berea, Clinton	Pen, Sil, Mis		*y*	
Cow Run, *Washington*	67	400-520?±	Cow Run	Pen		*y*	A
Thomas Fork, *Meigs*	71	1,570±	Berea	Mis		*y*	
New Castle, *Monroe*	43*x*	1,850±	Berea?	Mis		*y*	
Newells Run, *Washington*	43*x*	505-1,848	Cow Run, Berea Clinton?	Pen, Mis Sil		*y*	A
Sisterville, *Monroe*	42	1,875±	Big Injun Berea?	Mis		*y*	
Cormings, *Perry*	42	1,250-3,575±	Berea, Clinton	Sil		*y*	
Archers Fork, *Washington*	40*x*	1,950±	Berea	Mis			
Benwood, *Monroe*	39	1,865±	1st and 2d Cow Run Berea	Mis		*y*	
Moores Junction, *Washington*	39	1,900±	Berea	Mis		*y*	A
Sand Hill, *Washington*	38	1,900±	Mitchell 2d CR, Berea	Pen, Mis		*y*	
Wilson Run, *Washington*	38	1,900±	Berea, Big Injun	Mis		8, 65*y*	
Wingate Post Office, *Washington*	38	1,700-1,900±	Berea	Mis		*y*	
Guysville, *Monroe*	37	1,375-1,840±	Berea? Keener	Mis		*y*	
Jacksons Ridge, *Washington*	37	1,220-1,850 ±	Keener, Berea	Mis		*y*	
Hendershot, *Washington*	37	650-1,900?±	First Cow Run, Berea	Mis		*y*	
Hohman, *Washington*	37	1,900?±	Berea, Squaw	Mis		*y*	
Sheets Run, *Washington*	37	1,900?±	Maxton, Big Injun, Berea, Salt sand	Pen, Mis		*y*	
Elk Run, *Washington*	35	2,200-1,900?±	Berea	Mis, Dev		*y*	
Flints Mills, *Washington*	35	1,400-1,900?±	Big Injun, Berea	Mis, Dev		*y*	
Mitchell, *Washington*	35*y*	415-600-1,900?±	Mitchell and Cow Run, Berea, Br. shale	Pen, Mis, Dev		*y* *y*	
Moose Ridge, *Monroe*	34	970-1,875?±	Maxton Berea, Br. shale	Mis, Dev		*y*	
Whitacre, *Monroe*	34	1,875?±-2,425	Berea, Br. shale, Squaw	Mis, Dev		22*y*	
Jackson, *Vinton*	34	990±	Clinton, Cow Run? Berea	Pen, Mis		*y*	
Goose Run, *Washington*	34	150-300-1,875±	Goose Run, Mitchell, Berea?	Pen		*y*	
Clift, *Monroe*	33	1,070-3,600?±	Big Lime, Clinton, Berea?	Mis, Sil		*y*	
Oakfield, *Perry*	33	1,250-3,600	Clinton? Berea	Mis, Sil		*y*	
Germantown, *Washington*	32	820	Maxton, Germantown?			*y*	
Sycamore, *Monroe*	31		Keener, Berea?	Mis		*y*	
Woodsfield, *Monroe*	28		Berea?	Mis		*y*	
Wooster, *Monroe*	22		Berea	Mis		*y*	
Syracuse, *Meigs*	9	1,550±	Berea	Mis		*y*	
Lawrence	[illegible]		Lime, Berea	Mis, Dev		*y*	
Lima, *Allen*	48±	1,280±	Trenton	Ord			
Sandusky	48±	1,275-1,200±	Trenton	Ord			
Ottawa	47±		Trenton	Ord			

[a] Footnotes to column headings and explanation of symbols are on page 175.

TABLE 1.—(*Continued*)

Field, *County* Ohio	Age, Y[redacted] to End of 1933	Average Depth, Ft. To Top of Productive Zone	Producing Rock Name	Age[g]	Character[h]	Net Thickness, Average Ft.	Structure[i]
Seneca	47±	1,485±	Trenton	Ord			
Wyandot	47±	1,450±	Trenton	Ord			
Marion	*y*	2,515±	Trenton	Ord			
Hardin	*y*		Trenton	Ord			
Logan	*y*	1,442±	Trenton	Ord			
Shelby	35±		Trenton	Ord			
Darke	36±		Trenton	Ord			
Mercer	47±		Trenton	Ord			
Auglaize	45±		Trenton	Ord			
Van Wert	43±		Trenton	Ord			
Hancock	47±		Trenton	Ord			
Putnam	37±	1,450±	Trenton	Ord			
Paulding	31±		Trenton	Ord			
Henry	*y*	1,500	Trenton	Ord			
Wood	47±	1,200–1,500±	Trenton	Ord			
Lucas	42±	1,480±	Trenton	Ord			
Adams, *Harrison*	*y*						
Archers Fork, *Belmont*	43±	1,780	Cow Run, Berea	Pen, Mis			
Armstrong Mills, *Belmont*	*y*		Berea	Pen, Mis			
Ashland, *Ashland, Wayne*	*y*	650±	Berea	Pen, Mis			
Brink Hover, *Holmes, Knox*	*y*		Berea	Pen, Mis			
Brooklyn, *Cuyahoga*	*y*	3,080±	Clinton?	Sil			
Brushy Creek, *Belmont*	*y*		Berea	Mis			
Butler, *Richland*	*y*						
Cambridge, *Guernsey*	*y*		Injun, Berea	S, Mis			
East Liverpool, *Columbiana*	*y*	600±	Berea	Mis		60	A
Elyria, *Lorain*	*y*	2,450±	Clinton?	Sil			
Flushing, *Belmont*	*y*	1,950±	Berea	Mis			
Grafton, *Lorain*	*y*	2,450±	Clinton?	Sil			
Griffith, *Belmont*	*y*	1,950±	Berea?	Mis			
Harper, *Belmont*	*y*	1,950±	Berea?	Mis			
Homer, *Licking*	*y*	722±–2,275±	Berea, Clinton	Mis, Sil			
Hope Well, *Licking*		725±–2,275±	Berea, Clinton	Mis, Sil			
Kilbuck, *Holmes*	35	700 –2,450±	Berea, Clinton?	Mis, Sil		20	
Kilbuck, *Jefferson*			Berea	Mis			
Kilgore, *Carroll*		900	Berea	Mis			
Klondike, *Columbiana*	74±		Berea	Mis			
Lisbon, *Columbiana*	73		Berea	Mis			
Litchfield, *Lorain*	73	2,450±	Clinton? Berea	Sil			
Malaga, *Belmont*			Berea?	Mis			
McIntyre, *Jefferson*			Berea				
Medina, *Medina*	34±	450±	Berea	Mis			
Mingo, *Jefferson*			Berea				
Nashport, *Muskingum*		4,150±	Clinton?	Sil			
Newark, *Licking*	48	725–2,250±	Berea, Clinton	Mis, Sil			
New Waterford, *Columbiana*			Berea	Mis			
Ostego, *Muskingum*		4,150±	Clinton?	Sil			
Pleasantville, *Fairfield*		525±–2,350±	Berea, Clinton?	Mis, Sil			
Rockport, *Cuyahoga*		715±–3,075±	Berea, Clinton	Mis, Sil			
Scott, *Belmont*		960±–1,950±	Maxton? Berea?	Mis			
Stark County, *Stark*		4,450±	Clinton	Sil			
Starr, *Belmont*		960±–1,950±	Maxton, Berea	Mis			
Stumptown, *Belmont*		960±–1,950±	Maxton, Berea	Mis			
Sugar Grove, *Hocking, Fairfield*		517±–2,200±	Berea? Clinton	Mis, Sil			
Summit		2.500	Corniferous				
Tuscarawas	31	3,500±	Niagara, Berea	Sil			
Willer Brook, *Columbiana*			Berea	Mis			
Athens		1,110±	Berea	Mis			
Beallsville, *Monroe*		1,850±	Berea, Keener	Mis			
Black, *Monroe*		1,850±	Berea, Keener	Mis			
Bosworth, *Washington*			Cow Run, Berea, Warren	Pen, Mis			
Bremen Junction City, *Perry*		3,600±	Clinton? Berea	Sil			
Burkhart, *Monroe*		1,925±	Berea, Keener	Mis			
Chaseville, *Noble*		808±	Germantown?	Mis			
Cooker, *Monroe*		1,925±	Berea, Keener	Mis			
Decker, *Monroe*		1,925±	Berea, Keener	Mis			
Denbrow, *Monroe*		1,925±	Berea	Mis			
Egger, *Monroe*	*y*	1,975±	Cow Run Berea, Warren	Pen, Dev			
Fifteen, *Washington*	*y*	520±–1,975±–3,390±					
Fisher, *Monroe*	*y*	1,975±	Berea	Mis			
Gallipolio, *Gallia*	*y*	3,600±	Clinton	Sil			
Glouster, *Perry*	*y*	3,600±	Clinton	Sil			

[g] Footnotes to column headings and explanation of symbols are on page 175.

TABLE 1.—(*Continued*)

Field, *County* Ohio and West Virginia	Age, Years to End of 1933	Average Depth, Ft.	Producing Rock				
		To Top of Productive Zone	Name	Age[g]	Character[h]	Net Thickness, Average Ft.	Structure[i]
Hoffman, *Monroe*	*y*	1,925±	Berea	Mis			
Lewisville, *Monroe*	*y*	1,925±	Berea	Mis			
Locust Grove, *Vinton*	*y*	975±	Berea	Mis			
Marietta, *Washington*	*y*	1,950±–3,375±	Berea, Warren	Mis, Dev			
McArthur, *Vinton*	*y*	975±	Berea	Mis			
McConnelsville, *Morgan*	44*y*	1,275–126±	Cow Run? Berea	Pen			
Monroefield, *Monroe*	*y*	1,950±	Berea	Mis			
Moore, *Monroe*	*y*	1,950±	Berea	Mis			
Mt. Perry, *Perry*	*y*	3,600±	Clinton?	Sil			
Porterfield, *Monroe*	*y*	3,600±	Clinton?	Sil			
Rinards Mills, *Monroe*	*y*	1,950±	Berea, Keener	Mis			
Salt Run, *Noble*	*y*	810±	Germantown?	Pen?			
Schriver, *Monroe*	*y*	1,950±	Berea, Keener	Mis			
Summerfield, *Noble*	*y*	1,380	Berea	Mis			
Wahl, *Monroe*	*y*	1,975±	Berea, Keener	Mis			
White Cottage, *Monroe*	*y*	1,975±	Berea, Keener	Mis			
WEST VIRGINIA							
Burning Springs, *Wirt, Wood, Ritchie.*	73		Burning Springs, 1–2 Cow Run, Salt Sand, Murphy, Big Injun	Pen, Mis	S		A, S
Volcano, *Ritchie, Wood*	69		Salt	Pen	S		A
New Cumberland, *Hancock*	69		Berea	Mis	S	19	
Ogden, *Wood*	68		Berea	Mis	S		
Horseneck, *Pleasants*	65		Horseneck	Pen	S		
Tyler	63		Big Injun, Keener, Gordon	Mis	S		
Waverly, *Wood, Pleasants*	54		Cow Run	Pen	S		
California House, *Ritchie-Wirt*	54		Cow Run	Pen	S		A
Wellsburg, *Brooke*	51		Berea (1,650 ft.)	Mis	S	20	
Belmont, *Pleasants*	49±		Cow Run, Berea	Pen, Mis	S		A
Eureka, *Pleasants*	48±		Cow Run	Pen	S		
Mt. Morris, *Monongalia*	48		Big Injun, Bayard	Mis, Dev	S	104 25	
Moundsville, *Marshall*	46		Cow Run	Pen	S		
Turkey Foot, *Hancock*	45		Berea 1,259 ft.		S	22	
Cassville, *Marion*	44		Maxton-Big Inj., Gordon 30 ft., 4th 50 ft.	Mis, Dev	S S		
Cassville, *Monongalia*	44		Big Injun	Mis	S		AM
Mannington, *Marion*	44		Big Inj., Gordon, 4th	Mis, Dev	S		AM,T
Dolls Run, *Monongalia*	44		Big Injun, 5th	Dev	S		
St. Marys, *Pleasants*	44		Cow Run, Keener		S		
Fairview, *Marion*	43		Big Injun	Mis	S		AM
Cairo, *Ritchie*	43		Big Injun, Cairo, Salt sand	Mis, Pen	S		
Harrisville, *Ritchie*	43		Big Injun	Mis	S	100±	
Sistersville, *Tyler*	43		Big Injun	Mis	S		A
Doddridge	42		Cow Run, Maxton, Big Injun, Gordon, 5th, Stray	Pen, Mis, Dev	S S		
Center Point, *Doddridge*	42		Big Injun	Mis	S		
Tanner, *Gilmer*	42		Big Injun, Gantz	Mis, Dev	S		
Whiskey Run, *Ritchie-Wood*	42±		Big Injun, Keener	Mis	S		
Glenville, *Gilmer*	41		Big Injun	Mis	S		
Elk Fork, *Tyler*	41±		Keener, Big Injun	Mis	S		AM
Wetzel	41		Maxton, Big Inj., Gordon Stray 30 ft., 4th	Mis, Dev	S		
Smithfield, *Wetzel*	41		Big Injun, Gordon	Mis, Dev	S		AM
Whetstone Run, *Marion*	41		Big Inj., 4th	Dev	S		AS
Williamson, *Wood*	40		Cow Run, Big Injun	Mis	S		
Carson, *Hancock*	39		Berea	Mis	S	20±	S
Fink, *Lewis-Doddridge*	39		Berea	Mis	S	25±	T,AM
Flat Run, *Marion-Monongalia*	39		Big Injun, 4th	Mis, Dev			
Jakes Run, *Monongalia*	39		Big Injun, Gordon	Mis, Dev	S	*y*	
Willow Island, *Pleasants*	39		Cow Run	Pen	S		
Big Moses, *Tyler*	39		Big Injun	Mis	S	75	
Little Flint, *Doddridge*	39		Big Injun	Mis	S		
Board Tree, *Marshall*	38		Big Injun	Mis	S	310*y*	
Broard Run, *Pleasants*	38						
Hardman, *Tyler-Dodd*	38		Big Injun, Gordon	Mis, Dev	S		
Sancho Creek, *Tyler*	38		Big Injun	Mis	S		
Wick, *Tyler*	38		Big Injun	Mis	S		
Waverly, *Wood*	38		Cow Run	Pen	S		
Adaline, *Marshall*	37		Keener	Mis	S		

[a] Footnotes to column headings and explanation of symbols are on page 175.

TABLE 1.—(*Continued*)

Field, County West Virginia	Age, Years to End of 1933	Average Depth, Ft. To Top of Productive Zone	Producing Rock Name	Producing Rock Age[g]	Character[g]	Net Thickness, Average Ft.	Structure[g]
Belton, *Marshall*	37		4th, 5th, Gordon	Dev	S		
Cameron, *Marshall*	37		Big Injun	Mis	S		
Little Graveck, *Marshall*	37		1st Cow Run	Pen	S		
Cornwallis, *Ritchie*	37		Cow Run, Maxton	Pen, Mis	S		
Conway, *Tyler*	37		Big Injun	Mis	S		
Kyle, *Tyler*	37		Big Injun	Mis	S		
Stringtown, *Tyler, Dodd, Wetzel*	37		Big Injun, Gordon	Dev	S		
Piney Fork, *Wetzel*	37		Big Injun	Mis	S		
Murphytown, *Wood*	37		Cow Run	Pen	S		
Cabell	36		Injun lime, Berea	Mis	S		
Campbell Run, *Marion*	36		Big Inj., 4th, Gordon	Mis, Dev	S		
Flat Fk. of Poca, *Roane*	36		Big Injun	Mis	S		
Hendershot, *Wood*	36		Berea	Mis	S		
Sedalia, *Doddridge*	35		Gordon, Stray	Dev	S		
Arvillia, *Pleasants*	35		Cow Run, Berea	Pen, Mis	S		
Wetzel					S		
Folsom, *Wetzel*	35		Big Injun	Mis	S		
Stout, *Doddridge*	34		Gordon	Dev	S		
Wallace, *Dodd, Harrison*	34		Gordon	Dev	S		
Wolf Summit, *Harrison*	34		5th	Dev	S		
Kermit-Warfield, *Mingo*	34		Big Inj., Berea shale (Dev)	Mis	S		
Spencer, *Roane, Gilmer*	34		Berea	Mis	S		
Hurricane, *Roane*	34		Big Injun	Mis	S		
Garner, *Wetzel*	34		Gordon	Dev	S		
Mills, *Wetzel*	34		Big Inj., Gordon	Dev	S		
Salem, *Harrison*	33		Gordon	Dev	S		
Copley, *Lewis, Gilmer*	33		Gordon	Dev	S		S
Benson, *Lewis, Harrison*	33	2,514±	5th Sand	Dev	S		S
Quaker Fork, *Marion*	33		50-ft. Gordon, Gordon Stray	Dev			
Twilight, *Ohio*	33	1,000±	Big Injun				A, S
Steel Run, *Wetzel*	33	3,400±	Gordon				
Braxton	32		Maxton, Big Inj., Gordon, G. Stray				
Rosedale, *Braxton*	32	1,300±-1,500±	Rosedale gas sand, Rosedale salt sand	Pen			A, S
Yellow Creek, *Calhoun*	32	2,430±	Berea	Mis		38±	
Stumptown, *Gilmer*	32	2,680±	Salt sand	Pen			A
Indian Fork, *Gilmer*	32		5th sand	Dev		20±	S
Suckerrod, *Brooke*	31						
Rowles Run, *Calhoun, Roane*	31	2,195±	Berea	Mis		26	S
Newburne, *Gilmer*	31		Salt, Max., Squaw Berea	Pen, Mis			AS
Milton (Beckett), *Cabell*	30		Beckett	Mis		15	S
Silver Run, *Ritchie*	30		Salt sand, Big Injun	Pen, Mis			
Chester, *Hancock*	29		Berea	Mis		30±	
Majorsville, *Marshall*	29?	1,500±	Big Injun	Mis		160±	
Grandstaff Run, *Marshall*	29		Gas sand	Pen			
Big Springs, *Calhoun*	28						
Spindle Top, *Pleasants*	28		Cow Run	Pen			
Craddock, *Upshur*	28		Big Injun	Mis		45	A
Congo, *Hancock*	27						
Griffithsville, *Lincoln*	26		Berea	Mis		22	S
Follensbee, *Brooke*	26						
Holliday Cove, *Brooke*	26						
Clay	26						
Queen Shoals, *Clay*	26	1,500±	Big Injun	Mis			
Queen Shoals, *Kanawha*	26	1,500±	Big Injun				AS
Logansport, *Marion*	26		Gordon	Dev			AS
Miracle Run, *Monongalia*	26	1,900±	Big Injun	Mis			AS
Walton (Rock Ck), *Roane*	26		Big Injun				S
Branchland, *Lincoln*	25	2,000±	Berea	Mis		20	A
Bonds Creek, *Ritchie, Pleasant*							
Fowlersville, *Brooke*	24		Berea	Mis		24	
Bomont, *Clay*	24	1,800±	Big Injun	Mis			S
Mt. Claire, *Harrison*	24		5th sand	Dev			
Shinnston, *Harrison*	24		5th sand	Dev			S
Falling, Rk. Ck., *Kanawha*	24		Squaw, Weir	Mis			S
Rush Run (Clover), *Roane*	24		Big Injun	Mis			S
Tariff (Bright), *Roane*	24	1,875±	Big Injun	Mis		50±	S
Frenchton, *Upshur*	24		30-ft. Gordon, 4th	Dev			S
Dunlow, *Wayne*	24	1,275±	Big Injun	Mis		12	AS

[g] Footnotes to column headings and explanation of symbols are on page 175.

TABLE 1.—(*Continued*)

Field, *County* West Virginia	Age, Years to End of 1933	Average Depth, Ft.	Producing Rock				
		To Top of Productive Zone	Name	Age[a]	Character[a]	Net Thickness, Average Ft.	Structure[a]
Big Creek (C'vl.), *Logan*	23		Big Lime, Berea	Mis			AS
Bomont, *Clay*	22	1,800±	Big Injun	Mis			AS
Kanawha	22		Big Inj., Squaw, Weir-Berea	Mis			AS
Blue Creek, *Kanawha*	22	1,700±	Squaw	Mis		25	A
Weir, *Kanawha*	22	1,580±	Weir	Mis		25	S
Maidsville, *Monongalia*	22	1,650±	Big Injun	Mis			A
Hogans, *Monongalia*	22	1,625±	Big Injun	Mis			A
Warwood, Glenns Run, *Ohio*	22						
Boone	21		Big Lime, Big Injun, Berea	Mis			AS
Racine, *Boone*	21		Berea	Mis		22	A
Madison, *Boone*	20		Big Lime, Berea	Mis			A
Hackberry, *Kanawha*	20	2,210±	Weir	Mis		25±	S
Cabin Creek, *Kanawha*	19		Berea	Mis		20	AS
Barbour	18		Salt sand, Berea, Big Injun, Squaw	Pen, Mis			
Benson, *Barbour*	18		Benson	Mis			
Joes Creek, *Boone*	18		Berea	Mis			S
Burnsville, *Braxton*	18		Gordon, and G. Stray				A
Baldwin, *Gilmer*	17						
Little Gap, *Gilmer*	16?						
Kelley Creek, *Kanawha*	16		Berea	Mis			S
Breeden, *Mingo*	16						
Stover Fk. of Sycamore, *Raleigh*	16						
Pruntytown, *Taylor*	16						
Cox Mills, *Gilmer*	15						
Revere, *Gilmer*	15						
Little Licking Ck., *Wetzel*	15						
Marsh Fork, *Raleigh*	13						
Ethel, *Logan*	13						
Elkhurst, *Clay*	10						
Sandy Summit, *Roane*	14		Berea	Mis			
Bellville, *Wood*	22		Berea, Dev. Sh.	Mis, Dev			
Sarah, *Cabell*	9						
West Union, *Doddridge*	9						
Pratt, *Kanawha*	9		Salt sand, Max., Big Injun	Pen? Mis			
Hoopersville, *Nicholas*	9		Squaw	Mis			
Granny Creek, *Clay*	8		Salt, Big Injun, Berea	Pen, Mis			
Scott, *Putnam*	8		Big Injun	Mis			
Big Injun, *Wood*	?8±						
Boso, *Monroe*	4		Shale	Dev			
Huntington, *Cabell*	2	2,850±					

State[1]	Area Proved, Acres			Total Oil Production, Bbl.		
	Oil	Oil and Gas[a]	Gas	To End of 1933	During 1932	During 1933
Kentucky		350,000		130,000,000	4,621,000	
Ohio	880,000		905,400	563,250,000	4,610,000	4,300,000
West Virginia	578,750		990,550	387,269,000	3,835,000	

State[1]	Average Barrels per Well Daily, Nov., 1933	Total Gas Production, Millions Cu. Ft.			Number of Oil and/or Gas Wells			
					Completed to End of 1933	During 1933	At End of 1933	
		To End of 1933	During 1932	During 1933		Completed	Producing Oil Only	Producing Gas Only
Kentucky	0.84	270,550	29,000	27,000	42,000	216	14,900	3,000
Ohio	0.33	1,874,891	61,000	47,000	165,000	615	35,000	
West Virginia	0.76	5,227,894	101,000	90,000		227	13,900	21,000

[1] These state totals are merely estimates.

[a] Footnotes to column headin s and explanation of symbols are on page 175.

TABLE 2.—*Summary of Drilling Operations in Kentucky, Ohio and West Virginia*

(Figures in body of tabulation represent number of holes.)

County	Completed during 1933									
	Dry and/or Near-dry Holes									Productive Wells
	Total Depths, Ft.								Total	
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000		
KENTUCKY										
Ohio	50	0	0	0	0	0	0	0	50	25
Daviess	51	1	0	0	0	0	0	0	52	25
Hancock	27	0	0	0	0	0	0	0	27	15
McLean	21	1	0	0	0	0	0	0	22	12
Henderson	7	0	0	0	0	0	0	0	7	5
Muhlenberg	6	1	0	0	0	0	0	0	7	5
Barren	1	0	0	0	0	0	0	0	1	1
Warren	4	0	0	0	0	0	0	0	4	1
Knox	0	1	0	0	0	0	0	0	1	1
Webster	0	1	0	0	0	0	0	0	1	0
Allen	12	0	0	0	0	0	0	0	12	2
Hart	2	0	0	0	0	0	0	0	2	1
Pike	0	0	89	0	2	0	0	0	91	86
Martin	0	0	7	0	0	0	0	0	7	7
Knott	0	0	12	0	0	0	0	0	12	12
Floyd	0	0	18	0	0	0	0	0	18	18
Letcher	0	0	1	0	0	1	0	0	2	1
Perry	0	0	3	0	0	0	0	0	3	1
					0	0	0	0	0	0
Total Kentucky	181	5	130	0	2	1	0	0	319	218
OHIO										
Lima Field										
Allen	0	6	0	0	0	0	0	0	6	6
Auglaize	0	3	1	0	0	0	0	0	4	3
Hancock	0	2	2	0	0	0	0	0	4	3
Hardin	0	2	0	0	0	0	0	0	2	2
Logan	0	1	0	0	0	0	0	0	1	1
Lucas	0	1	2	0	0	0	0	0	3	2
Marion	0	0	1	0	0	0	0	0	1	0
Mercer	0	7	0	0	0	0	0	0	7	6
Sandusky	0	2	0	0	0	0	0	0	2	0
Seneca	0	28	0	0	0	0	0	0	28	24
Van Wert	0	1	0	0	0	0	0	0	1	1
Williams	0	0	1	0	0	0	0	0	1	1
Wood	0	2	0	0	0	0	0	0	2	1
Wyandot		59	2	0	0	0	0	0	61	44
Total Lima Field	0	114	9	0	0	0	0	0	123	94

County	Completed during 1933									
	Dry and/or Near-dry Holes									Productive Wells
	Total Depths, Ft.								Total	
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000		
OHIO										
Central Ohio										
Ashland	7	6	0	0	0	0	0	0	13	7
Carroll	0	1	0	0	0	0	0	0	1	0
Columbiana	0	0	0	0	0	1	0	0	1	1
Coshocton	1	0	2	14	0	0	0	0	17	15
Cuyahoga	1	0	1	2	0	0	0	0	4	1
Fairfield	0	3	10	0	0	0	0	0	13	11
Guernsey	4	8	6	0	0	0	0	0	18	12
Holmes	0	0	0	2	1	0	0	0	3	3
Knox	0	0	6	1	0	0	0	0	7	5
Licking	8	1	15	4	0	0	0	0	28	22
Lorain	4	0	16	0	0	0	0	0	20	13
Medina	38	0	0	0	0	0	0	0	38	24
Muskingum	0	0	2	6	5	0	0	0	13	9
Portage	0	0	0	1	2	0	0	0	3	0
Richland	2	0	0	0	0	0	0	0	2	1±
Stark	0	0	0	30	67	0	0	0	97	87
Trumbull	0	0	1	1	0	0	0	0	2	0
Tuscarawas	0	0	0	4	2	0	0	0	6	5
Summit	0	0	0	2	5	0	0	0	7	6
Wayne	3	0	0	0	0	0	0	0	3	1
Total Central Ohio	68	19	59	67	82	1	0	0	296	223
SOUTHEAST OHIO										
Athens	12	20	1	2	0	0	0	0	35	22
Belmont	9	27	14	0	0	0	0	0	50	34
Hocking	0	0	0	2	0	0	0	0	2	2
Jefferson	0	5	0	0	1	0	0	0	6	4
Harrison	0	0	0	0	5	0	0	0	5	0
Meigs	1	6	0	0	0	0	0	0	7	4
Monroe	2	6	0	0	0	0	0	0	8	6
Morgan	4	1	0	0	0	0	0	0	5	3
Noble	6	5	0	0	0	0	0	0	11	6
Perry	0	0	0	2	0	0	0	0	2	2
Vinton	6	3	0	0	0	0	0	0	9	5
Washington	8	7	2	3	0	0	0	1	21	13
Lawrence	0	0	12	1	0	0	0	0	13	11
Tota Southeast Ohio	52	84	20	21	6	0	0	1	197	112
Total Ohio	120	217	88	88	88	1	0	1	616	429

TABLE 2.—(*Continued*)

County	Completed Prior to Jan. 1, 1934									Completed during 1933									
	Dry and/or Near-dry Holes									Dry and/or Near-dry Holes									Productive Wells
	Total Depths, Ft.								Total	Total Depths, Ft.								Total	
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	7,000–8,000	9,000–10,000		0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000		
WEST VIRGINIA																			
Wirt	275	935	1,000	50	0	0	0	0	2,260±	3	3	2	0	0	0	0	0	8	
Wood	200	1,175	1,360	75	0	5	0	0	2,815±	0	5	1	0	0	0	0	0	6	
Ritchie	650	1,800	1,900	135	0	0	0	0	4,485±	0	13	29	0	0	0	0	0	42	
Pleasents	525	1,325	975	125	0	0	0	0	2,950±	0	10	3	2	0	0	0	0	15	
Kanawha	0	1,325	2,506	6	3	1	0	0	3,841	0	2	3	0	0	0	0	0	5	
Lincoln	0	350	3,635	11	1	0	0	0	3,997	0	0	12	0	0	0	0	0	12	
Putnam	0	180	365	12	2	0	0	0	559	0	0	2	1	0	0	0	0	3	
Mason	0	48	66	1	1	0	0	0	116±	0	1	0	0	0	0	0	0	1	
Cabell	0	103	512	203	1	0	0	0	819±	0	0	9	15	1	0	0	0	25	
Logan	0	90	204	3	0	0	0	0	297±	0	1	1	0	0	0	0	0	2	
Wyoming	0	2	15	1	0	0	0	0	18±	0	0	1	0	0	0	0	0	1	
McDowell	0	0	0	0	0	0	0	0		0	0	0	0	0	0	1	0	1	
Wayne	0	176	255	0	0	0	0	0	431±	0	0	3	3	0	0	0	0	6	
Mingo	0	91	101	2	0	0	0	0	194±	0	0	0	1	0	0	0	0	0	
Boone	0	430	819	16	0	0	0	0	1,266±	0	0	10	5	0	0	0	0	15	
Nicholas	0	22	85	4	0	0	0	0	111±	0	2	1	0	0	0	0	0	3	
Webster	0	5	3	0	0	0	0	0	8±	0	0	0	0	0	0	0	0	0	
Jackson	0	74	280	0	0	0	0	0	354±	0	1	0	0	0	0	0	0	1	
Roane	0	700	2,162	30	0	0	0	1	2,893±	0	0	10	8	0	0	0	0	18	
Clay	0	125	500	20	0	0	0	0	645±	0	2	2	0	0	0	0	0	4	
Calhoun	0	356	1,340	70	0	0	0	0	1,766±	0	24	38	2	0	1	0	0	65	
Braxton	0	95	480	5	0	0	0	0	580±	0	0	0	0	0	0	0	0	0	
Lewis	0	115	1,200	130	0	0	0	0	1,445±	0	0	0	0	0	0	0	0	0	
Gilmer	0	220	660	70	0	0	0	0	950±	0	3	11	0	0	0	0	0	14	
Upshur	0	60	115	25	0	0	0	0	200±	0	0	2	0	0	0	0	0	2	
Barbour	0	6	9	4	1	0	0	0	20±	0	0	0	0	0	0	0	0	0	
Preston	0	10	2	6	1	0	0	0	19±	0	0	0	0	0	0	0	0	0	
Harrison	0	600	2,200	425	1	0	1	0	3,227±	0	0	0	1	0	0	0	0	1	
Doddridge	50	250	1,175	350	0	0	0	0	1,825±		3	2	0	0	0	0	0	5	
Tyler	125	1,400	1,000	30	0	0	0	0	2,555±	1	3	0	0	0	0	0	0	4	
Marshall	75	670	400	80	0	0	0	0	1,225±	0	0	0	1	0	0	0	0	1	
Wetzel	150	425	1,680	500	0	0	0	0	2,755±	0	2	0	4	0	0	0	0	6	
Monongalia	40	310	1,350	250	0	0	0	0	1,950±	0	1	3	2	0	0	0	0	6	
Marion	75	200	1,800	600	0	0	1	0	2,676±	0	4	1	0	0	0	0	0	5	
Taylor	0	100	280	0	0	0	0	0	380±	0	0	0	0	0	0	0	0	0	
Ohio	0	90	290	30	1	0	0	0	411±	0	0	0	0	0	0	0	0	0	
Brooke	0	135	560	60	0	0	0	0	755±	0	0	0	0	0	0	0	0	0	
Hancock	0	60	630	75	0	0	0	0	765±	0	1	0	0	0	0	0	0	1	
Fayette	0	10	68	5	0	1	0	0	84±	0	0	0	0	0	0	0	0	0	
Raleigh	0	5	14	4	0	0	0	0	23±	0	0	0	0	0	0	0	0	0	
Mercer	0	3	3	2	0	0			8±	0	0	0	0	0	0	0	0	0	
Summers	0	1	1	2	0	0			4±	0	0	0	0	0	0	0	0	0	
Pocahontas	0	2	1	0	0	0			3±	0	0	0	0	0	0	0	0	0	
Greenbrier	0	1	0	0	0	0			1±	0	0	0	0	0	0	0	0	0	
Randolph	0	2	1	0	1	1			5±	0	0	0	0	0	0	0	0	0	
Pendleton	0	1	0	0	0	0			1±	0	0	0	0	0	0	0	0	0	
Tucker	0	0	0	0	1	0			1±	0	0	0	0	0	0	0	0	0	
Grant	0	0	1	1	0	0			2±	0	0	0	0	0	0	0	0	0	
Monroe	0	0	1	2	0	0			3±	0	0	0	0	0	0	0	0	0	
Total West Virginia[2]	2,165	14,083	32,004	3,420	14	9	2	1	51,698±	4	81	143	43	1	1	1	0	274	227

[1] On Feb. 2, 1934, there were 46 wells drilling in Eastern Kentucky.

[2] On the basis of the information now available, we estimate that more than 65,000 oil and/or gas wells, including non-productive wells, have been drilled in West Virginia.

Oil and Gas Development in Louisiana

By B. C. Craft,* Baton Rouge, La.

(New York Meeting, February, 1934)

The principal events in the oil and gas operations for Louisiana during 1933 have been the rapid development of the Converse field in Sabine Parish, the discovery of three new salt domes, one in North Louisiana and two in South Louisiana, increased development in the Iowa field on the Calcasieu-Jefferson Davis Parish line, and extensive geophysical operations over a wide territory. Other miscellaneous events worthy of mention are the continued leasing of prospective oil lands over a wide area, extension of production at the East Hackberry field, Cameron Parish, discovery of deep sands at Caillou Island, Terrebonne Parish, and the completion of several important wildcats.

Despite proration, oil production showed a substantial increase during 1933. The total output for this area was 25,599,802 bbl. as compared with 22,507,387 bbl. during 1932.

North Louisiana

There were 111 oil wells and 47 gas wells completed in North Louisiana during 1933 as compared with 109 oil wells and 33 gas wells during 1932. North Louisiana oil production decreased approximately 692,625 bbl. in 1933 from its 1932 figure. The normal decline in the old fields was partly offset by increased production at the Zwolle and Converse fields in Sabine Parish.

Acid treatment of wells in the Zwolle, Converse and Monroe fields was highly successful. The method of application has been described by H. K. Shearer, Geologist, Pelican Natural Gas Co., as follows:[1]

> With tubing in the hole and standing valve removed, the casing is filled with oil to the surface.
>
> The limestone solvent is pumped in through the tubing, at the same time bleeding off enough oil from the casinghead to equal the volume contained in the tubing plus the volume of open hole to be treated. The amount of solvent used in most of the wells treated was 1000 gal., which is enough to dissolve about 11 cu. ft. of chalk or limestone. After the computed amount of oil is bled off, the casinghead is closed and the remainder of the solvent is pumped in at whatever pressure is necessary to force it into the oil-producing horizon. The solvent is followed up with enough oil to

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[1] Personal communication.

drive all the acid out of the tubing, and a few barrels extra to drive the solvent further back into the formation, if this is considered desirable.

The well is shut in for a period of 48 hr. to give the acid time to complete its reaction.

The acid solvent will naturally act principally on the most broken and porous parts of the formation below the casing seat, but action may be confined closely to any particular part of the open hole if so desired. In case there is a danger of opening up salt water in the bottom of the hole, a heavy inert "blanket solution" is provided, which is placed in the hole first and remains below the acid, preventing action on that part of the hole. The level of the top of the acid is controlled by the amount of oil bled off from the casing.

A paraffin solvent is also supplied which is run in after the acid, in wells, where it is considered necessary, for the purpose of removing paraffin deposits from the tubing, liner, and face of the producing formation. The blanket solution and paraffin solvent were not used in any of the earlier treatments.

A detailed description of one well in the Zwolle field is given for illustration. The well when completed before acid treatment, except for the first day with the production of 60 bbl., had never made more than 11 bbl. and had declined to 8 bbl. per day.

The top to the marl and casing seat was 2438 ft., and the total depth 2627 ft., leaving 189 ft. of open hole to be treated. Before starting acid treatment, 71½ bbl. of oil was required to fill the casing, 16 bbl. was bled off during injection of the solvent, 12 bbl. followed up the solvent, leaving 67½ bbl. of oil in the hole. Quoting again from H. K. Shearer,

One thousand gallons of solvent were used. While the solvent was being pumped in, the pressure went up to 250 lb. on the casing, but there was a vacuum on the tubing all the time, due to the much greater weight of the solvent as compared to oil. When the solvent was followed up with the oil, the pressure rose to 250 lb. on the casing and 150 lb. on the tubing. Then the formation suddenly broke down and the pressure declined to a vacuum on both the casing and tubing.

When placed back on the pump, the well produced at the rate of 820 bbl. per day. Behavior of offset wells indicated that acid treatment in this well tapped a new source of oil, not connected by open breaks with any of the neighboring wells, and which would never have been produced by any of these wells by ordinary pumping.

The summary of the first 63 wells treated is as follows:

Daily Production	Bbl.
Before treatment	1345
First week after treatment	5648
30 days after treatment	2505
60 days after treatment	2041

The Converse field in Sabine Parish has been the most active area during 1933. Initiated in the Zwolle field, acid treatment has been used with success in Converse.

Acid treatment has also been highly successful in the Monroe gas field. The average chemical analysis of the Monroe Gas Rock is: silica 17.61 per cent; iron and aluminum oxide, 1.72; calcium carbonate, 78.69; magnesium carbonate, 1.57; sodium chloride, 0.41; and sulfates, trace.

Nearly 100 wells have been treated, with an increase in open flow of almost 200 per cent, indicating that the producing horizon is ideally constituted for acid treatment.

North Louisiana gas production decreased 4,297,000,000 cu. ft. in 1933 from its 1932 figure. Heavy withdrawal in the Richland field is reducing the rock pressure 10 to 12 lb. per month. At this rate the field will be dead in two years. The Louisiana Department of Conservation gage of Oct. 20, 1933, shows an open-flow capacity of 4,815,-367,000 cu. ft. per day from 858 wells in the Monroe field and 1,767,152,000 cu. ft. from 214 wells in the Richland field.

The most important deep test drilled in 1933 was the H. I. Morgan, Smith No. 2, sec. 22, 19N.11W., Bossier Parish, in the Bellevue field. This well was abandoned at a depth of 6137 ft., in the lower marine beds of the Trinity group, being stratigraphically the deepest well in Louisiana.

A new interior salt dome was proved when Gulf Refining Company's, Bridgman No. 1, sec. 20. 19N.8W., was abandoned after penetrating 10 ft. of rock salt at a total depth of 1922 feet.

South Louisiana

The Iowa field in Calcasieu and Jefferson Davis parishes has been active most of the year. It is the largest field in Louisiana and the third largest on the Gulf Coast. Eight sands, while not all productive, have been discovered and are found at the following average depths: 4515, 5135, 5585, 5935, 6525, 7006, 7115, and 7245 ft. Oil and/or gas wells have been completed in the first, second, third, fifth, sixth and seventh sands. However, of the 17 wells completed, 13 have been deepened to or completed in the deep zone at 7000 ft. Good indications have been obtained in the fourth and eighth sands.

The producing limits at East Hackberry, Cameron Parish, were extended to the northeast flank of the dome by the Texas Company's No. 10-B State, sec. 13, 12S.10W., which was completed flowing 1800 bbl. daily from a sand at 7266 feet.

The Texas Company's State Caillou Island Nos. 8 and 9, sec. 20, 23S.20E., opening new sands on the Caillou Island dome, Terrebonne Parish, were completed at 5987 and 4070 ft. It is expected that these horizons will result in sustained production on this dome.

The presence of a dome in the Harang area, Lafourche Parish, was proved when the Barnsdall Oil Co. Harang No. 1, lot 6, 17S.20E., was drilled into salt at 6990 feet.

The Texas Gulf Sulphur Co. proved the Lake Hermitage dome, Plaquemines Parish, when its Lafourche Basin Levee district No. 1, sec. 12, 18S.25E., was abandoned after penetrating 468 ft. of cap rock at 1450 feet.

TABLE 1.—*Oil and Gas Production in Louisiana*

Line Number	Field, *Parish*	Age, Years to End of 1933	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
	North Louisiana					
1	Caddo,[2] *Caddo*	30	32,500	0	15,040	47,540
2	Red River-Bull Bayou, *De Soto, Red River*	20	11,000	0	3,300	14,300
3	Lake Bisteneau, *Bienville*	18	0	0	600	600
4	Elm Grove,[6] *Caddo, Bossier*	18	320	0	14,600	14,920
5	Monroe, *Ouachita, Morehouse, Union*	18	0	0	123,340	123,340
6	Bethany & Waskam,[9] *Caddo*	18	0	0	1,800	1,800
7	Homer, *Claiborne*	15	0	3,024	0	3,024
8	Haynesville, *Claiborne*	13	0	7,480	0	7,480
9	Shongaloo, *Webster*	13	70	0	5,680	5,750
10	Bellevue, *Bossier*	13	1,360	0	160	1,520
11	Sligo, *Caddo*	12	0	0	4,160	4,160
12	Spring Hill-Sarepta, *Bossier, Webster*	12	570	0	1,120	1,690
13	Cotton Valley, *Webster*	12	3,900	0	2,700	6,600
14	Carterville, *Bossier*	10	720	0	2,720	3,440
15	Urania, *Grant, La Salle, Winn*	9	3,700	0	0	3,700
16	Richland, *Richland*	8	0	0	49,280	49,280
17	Pleasant Hill, *Sabine, De Soto*	7	800	0	0	800
18	Zwolle, *Sabine*	6	64,000[19]	0	0	64,000
19	Epps, *East and West Carroll*	6	0	0	1,200	1,200
20	White Sulphur Springs, *La Salle*	6	80	0	0	80
21	Holly, *De Soto*	4	80	0	10	90
22	Rodessa, *Caddo*	4	0	0	2,500	2,500
23	Sugar Creek, *Claiborne*	3	0	0	3,000	3,000
24	Clayton, *Concordia*	3	0	0	60	60
25	Converse, *Sabine*	2	1,600	0	0	1,600
26	Total North Louisiana		120,700	10,504	231,270	362,474
	South Louisiana					
27	Jennings, *Acadia*	33	235	0	0	235
28	Anse La Butte, *St. Martin*	32	25	0	0	25
29	Welsh, *Jefferson Davis*	31	50	0	0	50
30	Vinton, *Calcasieu*	24	265	0	0	265
31	Edgerly, *Calcasieu*	22	215	0	0	215
32	Pine Prairie, *Evangeline*	22	10	0	0	10
33	Houma, *Terrebonne*	22	0	0	720	720
34	Bayou Bouillon, *St. Martin*	18	12	0	0	12
35	New Iberia, *Iberia*	17	15	0	0	15
36	Lockport, *Calcasieu*	10	270	0	0	270
37	Starks, *Calcasieu*	9	50	0	0	50
38	Sulphur, *Calcasieu*	8	50	0	0	50
39	Sweet Lake, *Cameron*	8	250	0	0	250
40	Fausse Pointe, *Iberia*	7	10	0	0	10
41	Hackberry, *Cameron*	6	80	0	0	80
42	East Hackberry, *Cameron*	6	140	0	0	140
43	Sorrento, *Ascension*	6	20	0	0	20
44	White Castle, *Iberville*	5	30	0	0	30
45	Port Barre, *St. Landry*	5	75	0	0	75
46	Dog Lake, *Terrebonne*	5	10	0	0	10
47	Bayou Blue, *Iberville*	5	30	0	0	30
48	Black Bayou, *Cameron*	5	30	0	0	30
49	Lake Pelto, *Terrebonne*	5	20	0	0	20
50	Lake Barre, *Terrebonne*	5	100	0	0	100
51	Caillou Island, *Terrebonne*	4	30	0	0	30
52	Cameron Meadows, *Cameron*	3	20	0	0	20
53	Choctaw, *Iberville*	3	20	0	0	20
54	Lake Washington, *Plaquemines*	3	200	0	0	200
55	Leeville, *Lafourche*	3	210	0	0	210
56	Iowa, *Calcasieu, Jefferson Davis*	3	1,000	0	0	1,000
57	Darrow, *Ascension*	2	20	0	0	20
58	Gueydan, *Vermilion*	2	50	0	0	50
59	Total South Louisiana		3,542	0	720	4,262
60	Total Louisiana		124,242	10,504	231,990	366,736

[a] Footnotes to column headings and explanation symbols are on page 175.

[2] Includes following divisions: Cedar Grove, Shreveport, Jeems Bayou, Trees City, Monterey, Hart's Ferry, Ferry Lake, Mooringsport, Gilliam, Pine Island, Dixie and Blanchard.

[6] Includes Caspiana area.

[9] Includes the part of each field in Louisiana and the Greenwood area.

[19] Scattered production over 64,000 acres.

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			
	To End of 1933	During 1932	During 1933	Daily Average during Nov. 1933	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov. 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933
North Louisiana											
1	142,121,780	2,607,520	2,294,970	5,780	4,373	273	5	130,116	1,273	1,198	37
2	54,717,810	711,235	593,525	1,510	4,974	262	7	57,398	1,670	3,071	5
3								2,012	183	70	0.6
4	2,767,430	120,725	125,295	385	8,648	1,081	11	199,670	2,308	2,252	10
5								1,511,222	95,854	113,424	422
6								15,001	1,768	1,501	7
7	64,518,695	1,030,495	977,785	2,595	21,336	339	7	5,149	4,131	333	4
8	62,767,045	1,579,475	1,404,570	3,815	8,391	336	11	[14]	[14]	[14]	[14]
9	81,545	13,430	10,370	33	1,165	97	11	70,164	921	753	2
10	9,075,685				6,673	834		1,964	397	252	1
11								[15]	[15]	[15]	11
12	973,705	183,740	191,900	597	1,708	155	46	25,440[17]	307[17]	161[17]	0.6[1]
13	13,324,660	240,205	199,500	485	3,416	311	7	67,358	2,725	2,150	7
14	1,245,945	123,445	85,905	198	1,730	108	4	16,954	223	33	6
15	18,028,790	1,271,975	933,480	3,080	4,873	541	15	5	0	0	0
16								368,006	81,163	56,449	199
17	1,239,740	109,010	90,925	225	1,550	97	5				
18	10,199,260	2,624,035	2,938,985	6,235	159	20	36				
19								608	100	49	0.5
20	12,290				154	17					
21	682,880	100,915	74,850	185	8,536	776	26	[21]	[21]	[21]	[21]
22								9,395	1,383	7,784	26
23								11,455	3,958	3,695	13
24								11	0	0	
25	101,520		101,520	795	63	6	34				
26	381,858,780	10,716,205	10,023,580	25.918			16	2,491,923	198,364	193,175	751.7
South Louisiana											
27	50,377,217	398,330	406,250	996	214,371	3,898	34				
28	772,262	16,364	13,850	40	30,890	882	13				
29	571,004	14,421	16,180	42	11,420	1,427	38				
30	39,365,960	1,475,009	1,380,860	4,272	148,550	1,651	44				
31	8,148,839	70,360	53,820	197	37,902	292	10				
32	20,000	0	0		2,000	66					
33								14,295	0	0	
34	372,894	0	0		31,074	1,110					
35	72,347	0	0		4,823	105					
36	11,825,356	970,737	951,765	2,340	43,797	438	87				
37	1,570,072	291,643	332,655	824	31,401	785	46				
38	5,883,759	824,757	887,095	2,565	117,675	981	69				
39	2,011,474	267,132	335,960	1,178	8,045	201	236				
40	31,726	0	0		3,172	453					
41	1,903,654	197,092	212,060	428	23,795	1,189	21				
42	8,321,000	2,049,881	1,805,560	4,532	59,435	991	101				
43	523,027	22,012	15,145	32	26,151	1,743	11				
44	1,034,883	195,453	195,010	832	34,496	1,150	277				
45	3,023,821	556,603	1,005,790	2,042	40,317	1,152	136				
46	7,313	0	0		731	61					
47	61,837	1,891	0		2,061	103					
48	1,318,172	347,295	289,515	1,080	43,972	366	216				
49	157,651	21,446	18,460	43	7,882	143	43				
50	7,336,450	2,769,550	3,072,685	6,762	73,364	978	451				
51	348,720	0	342,715	2,144	11,624	129	2,144				
52	76,535	22,285	51,250	385	3,826	96	192				
53	350,000	148,321	101,590	272	17,500	437	91				
54	344,333	157,366	186,967	557	1,721	66	111				
55	788,566	265,976	361,285	1,522	3,755	150	504				
56	3,877,685	486,815	3,365,060	14,962	3,877	73	1,068				
57	10,730	805	9,925	29	536	16	29				
58	384,408	219,638	164,770	354	7,688	242	88				
59	150,891,695	11,791,182	15,576,222	48,430			242	14,295	0	0	
60	532,750,475	22,507,387	25,599,802	74,348				2,506,218	198,364	193,175	751.7

[14] Included with Homer.
[15] Included with Elm Grove.
[17] Spring Hill gas production; Sarepta gas production included with Cotton Valley.
[21] Included with Red River-Bull Bayou.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[6]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1933, Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injectionin to Reservoir[6]
North Louisiana																
1	3,700	10	58	49	1,026	0	26	1,052	2,067[3]	[4]	0	1,026	0	0	0	G
2	1,231	3	39	16	188	0	50	238	823–2,648	787–2,600	0	188	0	0	0	G
3	10	0	0	0	0	0	2	2	2,018–2,553	1,993–2,544	0	0	0	0	0	
4	248	2	1	0	35	0	49	84	[7]	[7]	0	35	0	0	0	
5	877	27	5	140	0	0	723	723	2,205	2,145	0	0	0	0	0	
6	67	2	0	0	0	0	23	23	1,823[3]–1,345	1,718[3]–1,280	0	0	0	0	0	
7	627	0	25	0	0	368	0	368	2,040–2,805	2,065–2,790	0	368	0	0	0	
8	765	0	5	1	0	351	0	351	5,092	4,530	0	351	0	0	0	G
9	91	0	0	0	3	0	13	16	2,680	2,665	0	3	0	0	0	
10	341	2	0	218	0	0	3	3	370–1,035–1,815	360–1,010–1,790	0	0	0	0	0	
11	53	1	0	1	0	0	27	27	845–1,745–2,480	885–1,710–2,445[16]	0	0	0	0	0	
12	43	0	0	1	13	0	5	18	2,691–3,063–3,165	2,686–3,059–3,143	0	13	0	0	0	
13	278	0	0	0	79	0	38	117	2,547–4,652	2,532–4,350	0	79	0	0	0	
14	132	0	8	3	50	0	0	50	3,085–3,170	3,080–3,143	0	50	0	0	0	
15	442	1	0	10	192	0	0	192	1,536	1,529	0	177	0	15	0	
16	283	2	16	13	0	0	205	205	2,447[18]	2,349	0	0	0	0	0	
17	57	0	0	0	44	0	0	44	3,237	3,175	0	44	0	0	0	
18	271	63	30	8	171	0	0	171	2,441	2,280	6	159	0	6	0	
19	4	0	0	0	0	0	4	4	2,344	2,336	0	0	0	0	0	
20	12	0	0	0	0	0	0	0	804	794	0	0	0	0	0	
21	12	0	0	0	7	0	1	8	2,851	2,838	0	7	0	0	0	
22	10	3	0	0	0	0	12	12	5,626	5,531	0	0	0	0	0	
23	8	2	0	0	0	0	10	10	4,420	4,314	0	0	0	0	0	
24	1	0	0	1	0	0	0	0	1,438	1,415	0	0	0	0	0	
25	41	40	1	4	35	0	0	35	1,871–3,232	1,689–3,150	4	31	0	0	0	
26	9,604	158	188	465	1,843	719	1,191	3,753			10	2,531	0	21	0	
South Louisiana																
27	511	0	8	1	31	0	0	31	1,944	1,833	1	30	0	0	0	
28	34	0	0	0	3	0	0	3	1,506	1,351	0	3	0	0	0	
29	66	0	0	0	11	0	0	11	1,158	1,148	0	11	0	0	0	
30	430	7	7	16	80	0	0	80	2,752	2,685	1	79	0	0	0	
31	172	2	1	2	18	0	0	18	3,145	3,107	2	16	0	0	0	
32	4	0	0	0	0	0	0	0	1,269	1,200	0	0	0	0	0	
33	10	0	0	0	0	0	0	0	2,469	2,448	0	0	0	0	0	
34	10	0	0	0	0	0	0	0	3,050	2,838	0	0	0	0	0	
35	4	0	0	0	0	0	0	0	2,121	2,049	0	0	0	0	0	
36	75	8	8	0	27	0	0	27	4,558	4,533	10	14	0	3	0	
37	24	2	0	1	18	0	0	18	2,272	2,224	2	16	0	0	0	
38	51	11	0	0	36	0	0	36	4,160	4,136	12	12	12	0	0	
39	8	1	0	0	5	0	0	5	6,284	6,262	4	1	0	0	0	
40	4	0	0	0	0	0	0	0	1,170	1,137	0	0	0	0	0	
41	47	0	7	1	19	0	0	19	3,331	3,296	0	19	0	0	0	
42	95	12	6	6	49	0	0	49	3,700	3,668	6	42	1	0	0	G
43	6	0	0	0	3	0	0	3	2,091	2,077	1	2	0	0	0	
44	3	1	0	0	3	0	0	3	5,505	5,433	2	0	1	0	0	
45	24	7	4	1	15	0	0	15	3,407	3,368	2	13	0	0	0	
46	1	0	0	0	0	0	0	0	1,068	1,056	0	0	0	0	0	
47	6	0	0	0	0	0	0	0	2,319	2,262	0	0	0	0	0	
48	8	0	0	0	5	0	0	5	4,535	4,446	3	2	0	0	0	
49	2	0	0	0	1	0	0	1	1,373	1,274	0	0	1	0	0	
50	25	9	5	0	15	0	0	15	3,836	3,777	14	0	1	0	0	
51	3	2	0	0	2	0	0	2	4,431	4,389	2	0	0	0	0	
52	4	2	0	0	2	0	0	2	4,844	4,822	0	2	0	0	0	
53	4	1	0	0	4	0	0	4	3,107	3,052	2	2	0	0	0	
54	9	6	2	2	6	0	0	6	1,154	1,135	6	0	0	0	0	
55	11	6	0	2	4	0	0	4	3,732	3,630	4	0	0	0	0	
56	17	13	0	1	16	0	0	16	6,762	6,742	16	0	0	0	0	
57	2	1	1	1	0	0	0	0	4,431	4,414	0	0	0	0	0	
58	5	3	0	1	4	0	0	4	3,972	3,924	2	2	0	0	0	
59	1,675	94	49	35	377	0	0	377			92	266	16	3	0	
60	11,279	252	237	500	2,220	719	1,191	4,130			102	2,797	16	24	0	

[3] Average depth of all wells completed.

[4] Producing horizons and average depths to top of horizons are as follows: Nacatoch, 1000 ft.; Chalk, 1437 ft.; Buckrange, 1823 ft., Tokio, 2260, and Trinity, 3647 ft.

[7] Average bottoms of wells and tops of productive zones are as follows: 840–804 ft., 1556–1548 ft., 1915–1896 ft., and 2496–2469 ft.

[16] One well completed in Glen Rose at 4270 ft.

[18] One well completed in Glen Rose at 2936 ft.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1933					Character of Gas, Approx. Average during 1933	
	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.
		1932	1933	Maximum	Minimum	Weighted Average				
North Louisiana										
1	415–1,650	950[5]	900[5]	25–46	14–26	38	0.50, 0.35	A, P	*y*	0.40[5]
2	350– 975	*y*	100	41.5	40	41	0.25	P	*y*	0
3	800–1,056	635–515	220-0						*y*	0
4	400–1,100	30–100–120	20–90–110	32	28	30	0.40	M	1,025	0.15[8]
5	1,050	510	501						1,017	0.13
6	400–1,325	580[10]	500[10]						*y*	0–0.24
7	*y*	0	0	38	35	36	0.80	P	3,300	15.0[12]
8	*y*	12	12	35	32	33	0.40	P	*y*	[12]
9	1,050	55	40	30	28	29	0.35	M	*y*	0
10	175– 750	0, *y*	*y*						970	0.34
11	375–1,825	910	733						972–1,057	0 –0.24
12	1,300	100	88	28	25	26	0.32	M	994–1,046	0.07–0.33
13	1,080–1,750	50–600	225	30–52	29–48	31	0.25, 0.09	M, P	866–1,004	1.5
14	1,250	*y*	0	44	38	41	0.27	P	994–1,046	0.07–0.33
15	*x*	0	0	22	19	20.5	0.30	A		
16	1,125	353	214						1,060	0.34
17	1,350	0	0	42	38	40	0.30	P		
18	750	0–750	0–250	45.5	38	40	0.20	P		
19	1,080	960	987						[illegible]	0
20	0	0	0							
21	900	*y*	840	45	38	41	0.22	P	*y*	[illegible]
22	2,400	2,250	2,250						1,060	0.40
23	1,800	1,600	1,500						1,125	0.56
24	630	630	630						[illegible]	[illegible]
25	[22]	[22]	[22]	46	42	43	0.15	P		
26										
South Louisiana										
27	295–550	0–200	0–150	26–34.5	21–34.5	28	0.17	A		
28	200	40	30	24	22	23	0.37	A		
29	50	0	0	22.6	22	22.3	0.15	A		
30	*x*	1*xx*	105	32	20	29.4	0.30	A		
31	*x*	3*x*	20	22	19	20	0.18	A		
32	*x*	0	0							
33	1,040	0	0							
34	1,600	0	0							
35	*x*	0	0							
36	2,200	1,800	1,800	41	23	33	0.12	A		
37	700	700	430	32	18	25	0.30	A		
38	850	790	790	36	19	27	0.31	A		
39	1,050	1,050	55[23]	32	29	39	0.12	A		
40	*x*	0	0							
41	500	0	0	32	19	20	0.37	A		
42	2,400	2,350	2,325	32	20	28	0.44	A		
43	625–1,600	325–1,600	325–1,600	31	26	28	0.38	A		
44	875	435	270	25	23	24	0.36	A		
45	450	350	350	27	20	26	0.33	A		
46	0	0	0							
47	300	0	0							
48	600	350	350	23.8	18	21	0.11	A		
49	200	0	0	16.8	16.8	16.8	0.55	A		
50	700	700	700	35.5	33	34	0.32	A		
51	1,000		1,000	34	32	33	*y*	A		
52	1,500	0	0	41	27	37	0.10	A		
53	600	65	40	29.5	25.5	27	0.15	A		
54	450	180	147	19	18	18.5	0.73	A		
55	3*xx*	3*xx*	315[35]	27	23	25	0.4	A		
56	2,510	2,500	2,500	43	25.4	41	0.37	A		
57	240	0	0	32	29.6	31	0.12	A		
58	1,150	*y*	60–180	27.5	27.1	27.3	0.12	A		
59										
60										

[5] Pressures and saturation in Blanchard area.
[8] Gasoline content of gas from deep horizon; gas from other sands is dry.
[10] Pressure on Augurs sand. [12] Produces casinghead gas.
[22] Wells flow for a few days after acid treatment.
[23] Same well has a pressure of 475 pounds on the tubing flowing through a $^{23}/_{64}$ inch choke.
[35] Tubing pressure.

TABLE 1.—(*Continued*)

Line Number	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Feet	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933[36]	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.	Reference to Text[k]
	North Louisiana									
1	[4]	CreU, CreL	C, S	Por	16	A	854	L. Trinity	6,351	
2	Nacatoch, Basal Upper Cret.	CreU	S	Por	19	AF	297	Glen Rose	6,149	
3	Ozan, Tokio	CreU	S	Por	35	D	11	L. Cret.	3,002	
4	Nacatoch, Ozan, Tokio	CreU	S	Por	8	A	40	L. Cret.	5,382	
5	"Monroe Gas Rock"	CreU	LS	23	50	A	91	Glen Rose	4,155	C
6	Nacatoch, Buckrange[11]	CreU, CreL	S, S, L	Por	120	A	49	Glen Rose	3,575	
7	Nacatoch, Buckrange[13]	CreU	S	Por	63	DF	194	Glen Rose	4,504	
8	Buckrange, Glen Rose	CreU, CreL	S	Por	25	A	61	Glen Rose	5,092	
9	Buckrange	CreU	S	Por	12	A	26	Glen Rose	4,750	
10	Nacatoch, Buckrange, Trinity	CreU, CreL	S	Por	8	DF	102	L. Trinity	6,137	
11	Nacatoch, Buckrange, Tokio[16]	CreU, CreL	S	Por	100	D	5	Glen Rose	4,276	
12	Buckrange, Tokio	CreU	S	Por	11	A	19	Glen Rose	5,120	
13	Buckrange, Glen Rose	CreU, CreL	S, A, S	27, 24	11	A	26	L. Trinity	7,006	
14	Buckrange, Tokio	CreU	S	Por	16	A	49	Trinity?	3,476	
15	Contact, Cane River-Wilcox	Eoc	S	Por	9	T	143	Tokio	6,463	
16	Tokio?, "Monroe Gas Rock"[18]	CreU, CreL	S, LS	Por	76	A	39	L. Trinity	2,856	O
17	Washita	CreL	S	Por	16	A	22	Glen Rose	5,063	
18	"Chalk Rock"	CreU	C	Crev	8	AF	360	Glen Rose	7,155	C
19	"Monroe Gas Rock"	CreU	LS	Por	8	D	10	Glen Rose[20]	3,142	
20	Jackson	Eoc	S	Por	9	N	8	Wilcox	2,435	
21	Tokio?	CreU	S	Por	11	N	27	Washita	3,373	
22	Glen Rose	CreL	L, S	Por	25	NF	18	L. Trinity	6,658	
23	Glen Rose	CreL	L	Por	20	A	12	L. Trinity	4,722	
24	Basal Jackson	Eoc	S	Por	23	N	6	Wilcox	3,705	
25	Nacatoch?, Saratoga Anona, Ozan, Washita	CreU, CreL	S, C	Por	10	D	26	Glen Rose	4,433	C
6							2,495			
	South Louisiana									
27	"Fleming," Marginulina?	Mio	S	Por	55	Ds	111	Vicksburg	8,903	
28	"Citronelle," "Fleming," Jackson	Pli, Mi, Eoc	S	Por	35	Ds	79	Jackson	1,500[23]	
29	Plio-Mio Contact	Pli, Mio	S	Por	8	D	42	U. Miocene	6,075	
30	L. Plio, "Fleming," Marginulina?	Pli, Mio	S	Por	90	Ds	192	Vicksburg?	5,630[24]	
31	L. Pliocene	Pli	S	Por	130	Ds	82	Jackson?	6,800[25]	
32	"Fleming"	Mio	S	Por	30	Ds	31	"Fleming"	5,112	
33	Upper, Marine Mio	Mio	S	Por	10	D	13	Miocene	5,645	
34	"Fleming"	Mio	S	Por	28	Ds	43	Vicksburg	3,910[26]	
35	L. Plio, "Fleming"	Pli, Mio	S	Por	46	Ds	28	"Fleming"	3,881	
36	"Fleming," Heterostegina	Mio	S	Por	100	D	13	*y*	7,656	
37	L. Plio, Cap Rock, "Fleming"	Pli, *x*, Mio	S	Por	40	Ds	51	Jackson?	7,207[25]	
38	"Fleming," Heterostegina	Mio	S	Por	120	Ds	29	Heterostegina	9,250[27]	
39	"Fleming"	Mio	S	Por	40	Ds	6	Miocene?	8,070	
40	"Fleming"	Mio?	S	Por	7	Ds	17	"Fleming"	5,119	
41	"Fleming"	Mio	S	Por	20	Ds	101	Vicksburg?	3,424[25,29]	
42	Cap Rock, "Fleming"	*x*, Mio	S	Por	60	Ds	60	Vicksburg?	3,035[25,30]	O
43	Cap Rock, Vicksburg	*x*, Olig	A, S	Por	15	Ds	22	Vicksburg	5,725	
44	"Fleming"	Mio	S	Por	30	Ds	4	"Fleming"	6,170	
45	Heterostegina	Mio	S	Por	35	Ds	14	Heterostegina	4,610[27]	
46	L. Plio	Pli	S	Por	12	Ds	9	U. Miocene	6,347	
47	"Fleming"	Mio	S	Por	20	Ds	10	"Fleming"	6,103	
48	Cap Rock, U. Mio, Heterostegina	*x*, Mio	L, S	Por	120	Ds	18[31]	Heterostegina	6,200[32]	
49	Upper Marine Mio	Mio	S	Por	55	Ds	6	U. Miocene	4,775	
50	Upper Marine Mio	Mio	S	Por	75	Ds	6	U. Miocene	6,790	
51	Upper Marine Mio	Mio	S	Por	90	Ds	5	U. Miocene	5,981	O
52	"Fleming"	Mio	S	Por	40	Ds	2	U. Miocene	6,921	
53	"Fleming"	Mio	S	Por	40	Ds	12[33]	"Fleming"	6,290	
54	Cap Rock, Super Cap	*x*, Pli	L, S	Por	26	Ds	26	Miocene[34]	5,860	
55	Upper Marine Mio	Mio	S	Por	25	Ds	2	U. Miocene	5,662	
56	"Fleming," Heterostegina, Marginulina	Mio	S	Por	53	D	3	Marginulina	7,590	O
57	Upper Marine Mio	Mio	S	Por	34	Ds	6	U. Miocene	6,052	
58	"Fleming"	Mio	S	Por	31	Ds	8	Miocene	8,007	
59							1,051			
60							3,546			

[11] Produces from contact of Upper and Lower Cretaceous, contact of Washita and Fredericksburg, Glen Rose, and Lower Glen Rose.

[13] Goes also under names of Oakes sand and Haynesville sand. [16] One well completed in Glen Rose at 4270 ft.

[20] Abandoned in igneous rock. [23] Deepest well abandoned at 6204 feet in the Miocene. [24] Drilling in heaving shale.

[25] Abandoned in heaving shale, correlated either as basal Vicksburg or top of the Jackson.

[26] Deepest well abandoned at 6471 ft. in Lower Miocene. [27] Abandoned in salt.

[29] Deepest well abandoned at 7834 feet. [30] Deepest well abandoned at 8334 feet. [31] Includes 7 Sulfur tests.

[32] Deepest test completed at 6631 feet. [33] Includes 8 sulfur tests. [34] Abandoned in salt at 6179 feet.

[36] Dry holes drilled in fields and those drilled in defining producing limits.

TABLE 2.—*Summary of Drilling Operations in Louisiana*
(Figures in body of tabulation represent number of holes.)

Parish	Completed Prior to Jan. 1, 1934: Dry and/or Near-dry Holes, Total Depths, Ft.: 500–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000	Total	Productive Wells (for Details, See Table 1)	Completed during 1933: Dry and/or Near-dry Holes, Total Depths, Ft.: 500–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	Total	Productive Wells (for Details See Table 1)	Drilling or Incomplete at End of 933: Within Fields	Exploratory
Acadia	0	22	30	21	10	9	1	1	4	0	98	511	0	2	1	0	0	1	0	0	1	5	0	1	3
Allen	0	0	0	0	0	0	1	0	0	0	1		0	0	0	0	0	0	1	0	0	1			0
Ascension	1	8	5	4	9	3	1	0	0	0	31	8	0	1	1	0	3	0	1	0	0	6	1	2	0
Assumption	10	4	1	0	0	0	1	0	1	0	17		0	0	0	0	0	0	0	0	1	1			0
Avoyelles	1	3	3	2	0	0	0	0	0	0	9		0	0	1	0	0	0	0	0	0	1			1
Beauregard	0	2	0	6	2	0	0	0	0	0	10		0	0	0	2	0	0	0	0	0	2			0
Bienville	2	6	39	24	4	0	0	0	0	0	75	10	0	1	0	2	1	0	0	0	0	4			0
Bossier[1]	35	50	126	74	6	2	1	0	0	0	294	700	1	2	1	1	0	0	1	0	0	6	4		4
Caddo	65	220	684	61	18	1	2	0	0	0	1,051	3,851[2]	0	4	10	4	0	0	1	0	0	19	14	1	7
Calcasieu	2	26	79	65	45	18	16	2	0	1	254[2]	1,485[3]	0	0	2	4	7	0	1	3	1	18	36	20	3
Caldwell	4	12	8	7	1	0	0	0	0	0	32		0	1	0	1	0	0	0	0	0	2			2
Cameron	0	17	8	17	5	7	1	3	0	0	58	162	0	0	3	4	1	1	2	0	1	12	15	5	2
Catahoula	1	4	6	15	1	0	0	0	0	0	27		0	1	1	1	0	0	0	0	0	3			0
Claiborne	7	137	216	59	8	3	1	0	0	0	431	773	0	0	1	1	3	0	1	0	0	6	2		1
Concordia	0	4	3	3	0	0	0	0	0	0	10	1	0	0	1	0	0	0	0	0	0	1			0
De Soto	5	30	218	82	5	1	2	0	0	0	343	336	0	4	7	5	0	0	0	0	0	16	1		11
East Baton Rouge	0	3	3	0	0	0	1	0	0	0	7		0	0	0	0	0	0	1	0	0	1			0
East Carroll	0	7	3	2	0	0	0	0	0	0	12	3	0	0	0	1	0	0	0	0	0	1			0
East Feliciana																									
Evangeline	0	7	12	1	5	1	0	0	0	0	26		0	2	0	0	0	0	0	0	0	2			1
Franklin	0	5	8	2	1	0	0	0	0	0	16		0	0	0	0	0	0	0	0	0	0			0
Grant	0	39	32	2	0	0	0	0	0	0	73	10	0	0	1	0	0	0	0	0	0	1			2
Iberia	31	13	4	9	12	6	2	0	0	0	77	98[4]	0	0	0	0	0	0	0	0	0	0			1
Iberville	5	3	4	7	3	3	3	0	0	0	28	12	0	0	1	0	0	1	1	0	0	3	1		0
Jackson	0	5	7	8	0	0	0	0	0	0	20		0	0	0	0	0	0	0	0	0	0			1
Jefferson	0	0	1	0	0	0	0	1	0	0	2		0	0	0	0	0	0	0	0	0	0			0
Jefferson Davis	4	17	15	8	10	6	2	0	0	0	62[2]	75	0	1	0	0	0	2	0	0	0	3		3	2
Lafayette	0	1	0	0	0	0	1	0	0	0	2		0	0	0	0	0	0	0	0	0	0			0
Lafourche	0	34	5	3	5	4	1	0	0	0	52	11	0	2	0	0	0	0	0	0	0	2	6	5	1
La Salle	15	125	22	7	0	1	1	0	0	0	171	419	0	0	0	0	0	0	0	0	0	0	1		0
Lincoln	1	0	13	11	2	0	0	0	0	0	27		0	0	0	0	0	0	0	0	0	0			0
Livingston	0	0	4	0	0	0	0	0	0	0	4		0	0	0	0	0	0	0	0	0	0			0
Madison	1	1	0	1	0	0	0	0	0	0	3		0	0	0	0	0	0	0	0	0	0			0
Morehouse	4	4	15	20	0	0	0	0	0	0	43	223	0	0	2	1	0	0	0	0	0	3	5	1	0
Nachitoches	5	40	36	16	3	0	0	0	0	0	100		1	1	1	2	0	0	0	0	0	5			4
Orleans																									
Ouachita	2	0	35	12	1	0	0	0	0	0	50	504	0	0	0	0	0	0	0	0	0	0	17	1	3
Plaquemines	4	6	3	0	0	2	0	0	0	0	15	9[5]	0	14	3	1	0	0	0	0	0	18	6	1	1
Point Coupee	2	3	0	0	0	0	0	0	0	0	5		1	0	0	0	0	0	0	0	0	1			0
Rapides	0	4	4	15	13	1	0	0	0	0	37		0	0	0	2	0	0	0	0	0	2			1
Red River	2	22	151	23	0	0	0	0	0	0	198	895	0	0	1	0	0	0	0	0	0	1	2	0	2
Richland	5	5	43	7	1	0	0	0	0	0	61	283	0	0	0	0	0	0	0	0	0	0	2	0	0
Sabine	12	37	357	59	16	2	0	0	0	0	483	366	0	10	75	8	3	1	0	0	0	97	99	50	1
St. Bernard	1	0	0	0	0	0	1	0	0	0	2		0	0	0	0	0	0	1	0	0	1			2
St. Charles																									
St. Helena	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0			0
St. James	0	1	1	0	0	0	0	0	0	0	2		0	0	0	0	0	0	0	0	0	0			0
St. John the Baptist																									
St. Landry	1	0	4	6	3	0	0	0	0	0	14	24	1	0	0	4	1	0	0	0	0	6	7	3	1
St. Martin	16	54	27	17	14	10	6	0	0	0	144	44	0	0	0	0	0	1	0	0	0	1			1
St. Mary	3	15	8	9	5	3	2	1	0	0	46		0	0	0	0	0	0	0	0	0	0			0
St. Tammany	0	0	2	2	0	0	0	0	0	0	4		0	1	0	0	0	0	0	0	0	1			0
Tangipahoa	0	0	2	1	1	0	0	0	0	0	4		0	0	0	0	0	0	0	0	0	0			0
Tensas	1	1	1	2	0	0	0	0	0	0	5		0	0	0	1	0	0	0	0	0	1			0
Terrebonne	1	15	21	6	9	7	6	1	0	0	66	40	0	0	2	3	2	1	2	0	0	10	10	7	0
Union	0	3	56	24	1	0	0	0	0	0	84	150	0	0	1	3	0	0	0	0	0	4	5		0
Vermilion	1	0	2	1	3	1	2	0	1	0	11	4	0	0	0	0	4	1	0	1	0	6	2	1	1
Vernon	1	1	3	5	1	1	0	0	0	0	12		0	0	0	5	0	2	0	0	0	7			1
Washington																									
Webster	5	21	80	40	9	3	0	1	0	0	159	412	0	1	6	1	1	0	0	0	0	9			0
West Baton Rouge	0	0	1	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0			0
West Carroll	0	0	6	4	0	0	0	0	0	0	10	1	0	0	1	0	0	0	0	0	0	1			0
West Feliciana	0	1	3	3	3	0	0	0	0	0	10		0	0	0	0	0	0	0	0	0	0			0
Winn	5	42	15	6	6	0	0	0	0	0	74	13	0	1	0	0	0	0	0	0	0	1			1
Total	261	1,080	2,435	779	241	95	55	10	6	1	4,963	11,433	4	49	123	57	26	11	13	4	4	291	236	102	61

[1] Sixty-nine wells abandoned between 100 and 500 ft. [2] Incomplete. [3] Includes 712 sulfur wells.
[4] Includes 90 sulfur wells. [5] Does not include sulfur wells.

Salt was drilled into for the first time at Cameron Meadows, Cameron Parish, and at Darrow, Ascension Parish.

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Oil and Gas Development in Michigan during 1933

By Theron Wasson,* Chicago, Ill.

(New York Meeting, February, 1934)

The Central Michigan area held first place in the state during the year. Midland and Isabella, the leading counties in 1932, produced most of the oil in 1933. The Porter field southeast of Mt. Pleasant and along the same structural trend saw the greatest drilling activity. In Porter during the year 117 new wells were drilled. Under proration these wells produced 3,583,617 bbl., or nearly one-half the total for the state, which has been estimated at 7,947,695 bbl. The Porter field is already outlined on all sides except the northwest. It probably reached its peak in 1933. Unless a new field of some magnitude is developed in 1934, Michigan will see a continuous decline. The Greendale extension to the old Mt. Pleasant field furnished the new flush for 1932. In 1933

Table 1.—*Oil and Gas Production in Michigan*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres				Total Oil Production, Bbl.				Average Oil Production, Bbl.	
			Oil	Oil and Gas[a]	Gas	Total	To end of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Per Acre to End of 1933[b]	Per Well Daily during Nov., 1933
1	Saginaw, *Saginaw*	9	1,660			1,660	1,145,362	51,082	53,924	97	609	1
2	Muskegon, *Muskegon*	6	4,200	200		4,400	6,076,479	475,624	274,445	522	1,447	3
3	Mt. Pleasant, *Midland, Isabella*	6	9,120			9,120	15,343,692	5,854,951	3,126,323	5,689	1,682	14
4	Leaton, *Isabella*	4	620			620	984,527	258,454	306,618	578	1,588	34
5	Vernon, *Isabella*	4	1,320			2,200	1,124,858	318,252	535,722	2,357	852	90
6	Vernon—Stray Gas Sand[1]				880[1]							
7	Porter, *Midland*	2	5,600			5,600	3,611,404	28,168	3,583,617	20,171	645	188
8	Hart, *Oceana*	1	500			500	46,404		46,404	202	93	25
9	Ogemaw, *Ogemaw*	½	500			500	18,982		18,982	120	38	40
10	Edmore, *Montcalm*	0							1,660	95[2]	2	95
11	Gratiot, *Gratiot*	7			400	400						
12	Clare, *Clare*	4			300	300						
13	Broomfield, *Isabella*	4			5,100	5,100						
14	Big Rapids, *Mecosta*	½			3,500	3,500						
	Total		23,520	200	10,180	33,900	28,351,708	6,986,531	7,947,695			

[a] Footnotes to column headings and explanation of symbols are on page 175.
[1] Stray sand gas wells are within area where oil production is from Monroe.
[2] During December, 1933.

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there was very little new development in Greendale other than a short extension to the east and the drilling of inside locations. All wells in the Mt. Pleasant-Greendale field are on the pump. This field produced 3,126,323 bbl. during the year from 324 wells, or an average of 27 bbl. per well per day for the year.

The Porter field, like Mt. Pleasant, is producing from the Dundee formation of Devonian age at a depth of 3400 ft. The total thickness of pay does not average more than 10 or 15 ft. of porous limestone. Small wells offset big producers and there is no consistent water level. Salt water found in the pay zones appears to be trapped with the oil and in some wells does not increase materially as the oil is produced; others develop a big percentage of salt water in a short time. Although rapidly developed, the Porter field has not been overdrilled, and a spacing of one well to 10 acres has been maintained.

Several new oil and gas fields were discovered in 1933. They are difficult to evaluate until more drilling is done and the production of wells so far drilled has been observed. At the beginning of the year 1934, however, there are no new fields with possibilities that can be compared with the fields of the Midland-Isabella area.

In the order of their discovery, the possible oil fields of 1933 are: Hart, Oceana County; Ogemaw, Ogemaw County; and Edmore, Montcalm County. Each of these new fields is producing oil from the Traverse limestone of Devonian age. In spite of large initial productions first

TABLE 1.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933	
						During 1933		At End of 1933						Number of Wells	
	To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Completed To End of 1933	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping
1					280	0	50	0	140	0	140	1,850	1,820		140
2	5,293	288	468	2	398	4	41	0	175	23	198	2,075	2,050		198
3					368	64	6	1	324	0	324	3,575	3,510		324
4					28	2	1	2	17	0	17	3,675	3,615		17
5					49	25	3	4	36		44	3,725	3,700		36
6	334	86	195	1						8		1,405	1,395		
7					121	117	5	1	116		116	3,450	3,410	22	94
8					14	14	4	2	10		10	1,900	1,860		10
9					4	4	0	5	4		4	1,750	1,700		4
10					1	1	0	0	1		1	3,120	3,045	1	
11	2	0	2	0	8					8	8	510	500		
12	0	0	0	0	7					7	7	1,420	1,400		
13	928	455	446	4	20	3				20	20	1,350	1,300		
14	0	0	0	0	4	4	0	0		4	4	1,475	1,450		
	6,557	829	1,111		1,302	238	110	15	823	70	893			31	823

reported, the combined daily average for the month of November of these fields was 450 bbl. from 11 wells. Further development of the possibilities of the Traverse lime and deeper drilling to the Dundee, however, may lead to discoveries of major importance.

One new gas field was discovered near Big Rapids in Mecosta County about halfway between the Mt. Pleasant field and Muskegon. Four wells have been drilled to the "stray" sand, which lies above the Marshall in this area where wells are 1450 ft. deep. One well in this field had an initial open flow of 30 million cubic feet per day.

Gas produced and sold in 1933 came principally from Muskegon, Vernon and Broomfield. Very little new drilling was done in the older shallow gas fields at Broomfield, Clare and Gratiot.

The deep test being drilled by the Newago Oil and Gas Co. on the Bates farm in Newago County and reported in 1932 as being in the Niagara limestone at 6020 ft. continued drilling in 1933, and has reached a depth of 6548 ft., where it is reported to be in the Trenton limestone. This is the deepest test in the state.

Acid was used in all the lime fields of the state during the year with considerable success. The use of acid with an inhibitor to prevent pipe corrosion started in Michigan in an experimental way in 1931. It has since taken its place as an established aid to production.

Proration in the State of Michigan became generally effective on Oct. 6, 1933, although prior to that date there was some voluntary prora-

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[e]	Character of Oil, Approx. Average during 1933			Character of Gas, Approx. Average during 1933		Producing Rock					Deepest Zone Tested to End of 1933	
	Initial	Gravity A.P.I. at 60°F. Weighted Average	Sulfur, Per Cent	Base[f]	B.t.u. per Cu.Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Structure[j]	Name	Depth of Hole, Ft.
1		43	0.68	P			Berea	Mis	S	Por	A	Sylvania	3,970
2		37	1.45	P	1,032	1	Traverse, Monroe	Dev	LD	Por	A	St. Peter	4,754
3		42	0.165	P			Dundee	Dev	L	Por	A	Sylvania	4,821
4		43	0.40	P			Dundee	Dev	L	Por	A	Monroe	3,825
5		44	0.45	P			Monroe	Dev	L	Por	AF	Monroe	3,670
6	570						Stray	Mis	S	Por			
7		42	0.29	P			Dundee	Dev	L	Por	A	Monroe	3,677
8		34	y	P			Traverse	Dev	L	Por	A	Dundee	2,407
9		36	0.34	P			Traverse	Dev	L	Por	A	Sylvania	5,405
10		42	y	P			Traverse	Dev	L	Por	X	Traverse	3,120
11							Parma	Penn	S	Por	A	Dundee	3,100
12	590						Stray	Mis	S	Por	A	Monroe	4,055
13	550				1,080		Stray	Mis	S	Por	A	Dundee	3,734
14							Stray, Marshall	Mis	S	Por	A	Dundee	3,790

TABLE 2.—*Summary of Drilling Operations in Michigan*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934									Completed during 1933							Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes								Productive Wells	Dry and/or Near-dry Holes						Productive Wells		
	Total Depths, Ft.									Total Depths, Ft.								
		1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	Total	(For Details See Table 1)		1000–2000	2000–3000	3000–4000	4000–5000	Total	(For Details See Table 1)	Within Fields	Exploratory
Clare		5		3	7			15	7				1	1	2	0	0	1
Gratiot	4	2	6	10				22	8	2	1		2		5	0	0	1
Isabella		8	1	58	3			70	255		2		4		6	33	25	7
Mecosta		2		3	1			6	4							4	1	0
Midland				49	1			50	331				15		15	170	58	3
Muskegon		33	82	1	1			117	398		4	9			13	4	4	1
Oceana		12	14	3	1			30	14		4	5			9	14	7	6
Ogemaw		3	3	1		1		8	4		1	1			2	4	3	10
Alcona	2	2						4										
Allegan		10	5					15			1				1			
Alpena	6	4						10										
Antrim																		
Arenac		1	1					2										
Barry		2	1					3										
Bay		3	1	4				8										
Benzic		1						1										
Berrien	9	4						13										
Branch		2						2										
Calhoun					1			1										
Cass	1	4	6					11		1		1			2			1
Charlevoix	2							2										
Cheboygan		2	1					3										
Clinton																		
Crawford			3					3										
Delta																		
Eaton		1	6		1			8										1
Emmet	3							3										
Genesse		1	3					4										
Gladwin				1				1										1
Hillsdale		3						3										
Huron		4		2	1			7										
Ingham		1	1					2										
Ionia																		
Iosco			2					2										
Jackson		2	3					5										1
Kalamazoo		1	1	1				3										
Kalkaska			1					1										
Kent			3	3	1			7										
Lake			2	2				4										
Lapeer		1	2					3										1
Leelanan			1					1										
Lenawee	3	3	4	1				11										
Livingston	4	11	1	1	1			18										
Macomb	8	5	3	1				17			2				2			1
Manistee	1	6	6			1		14										
Mason	1	1	11	4				17										
Missaukee				2				2										
Monroe	3	9	11	1				24			1				1			1
Montcalm				3	1			4	1									1
Montgomery	2							2										
Newago		1	11	5		1		18										
Oakland		3	2					5				1			1			1
Oceola				1				1										
Ottowa		4	3	2	1		1	11										1
Presque Isle		2		1				3										
Roscommon				1				1										
St. Joseph	1	1						2										
St. Clair	1	6	6		1			14			3	1			4			1
Saginaw		30	20	10	1		1	62	280		2		1		3			3
Sanilac		4	1					5										5
Shiawassee		3	10					13				1			1			
Tuscola			2	1				3										2
Van Buren	1	8	3					12										
Wayne	2		3		1			6										
Washtenaw	1	2	1					4										1
Wexford				3	1			4					1		1			
Total	55	213	247	178	25	3	2	723	1302	3	13	16	22	1	68	238	98	51

tion in the Porter field made necessary by market conditions. From Oct. 6 to Oct. 12, inclusive, all wells in Porter Township had an allowable of 100 bbl. plus 40 per cent of potential production from 101 to 500 bbl., plus 35 per cent of potential from 501 to 1000 bbl., plus 30 per cent of

FIG. 1.—OIL AND GAS FIELDS OF MICHIGAN.

potential from 1001 to 2000 bbl., plus 25 per cent of all potential over 2000 bbl. All wells are shut in for 15 days after completion and before the potential is taken. Further changes made by the Committee during the year are as follows:

Date to Date, Inclusive	Free Oil, Bbl.	Percentage of Potential Allowed above 100 Bbl.
Oct. 13–Nov. 2	100	30
Nov. 3–Nov. 12	100	20
Nov. 13–Nov. 30	100	15
Dec. 1–Dec. 21	100	12
Dec. 22–Dec. 31	100	10

The potential of a new, flowing well is determined by an open-flow test of 6 hr., the production of the last 2 hr. being multiplied by 12 to ascertain the 24-hr. potential. The water content is determined by frequent "shake-outs" during the 6 hr., and from this average the volume of water is estimated and subtracted from the gross fluid. Potential of pumping wells is determined by a 24-hr. pumping test.

The Federal Government's allocation to the State of Michigan was established as 30,000 bbl. per day on Oct. 6, 1933, and continued at that rate to Nov. 30. Dec. 1 it was reduced to 29,000 bbl. per day, which is the rate allowed to the end of the year.

In Table 1, production figures for the various fields up to November are from the Michigan State Conservation Department. November and December totals have been estimated from pipe line runs.

Acknowledgments

Mr. W. A. Thomas, Division Geologist of the Pure Oil Co. at Saginaw, and Mr. George A. Bell, Chief Scout of the same company, assisted in the collection of information on Michigan fields. Dr. Robert B. Newcombe and Mr. F. R. Frye, of the Michigan State Geological Survey furnished production data and other information. Dr. Newcombe's report[1] on the Oil and Gas Fields of Michigan, published in 1933, has been used as a reference.

[1] R. B. Newcombe: Oil and Gas Fields of Michigan. Mich. Geol. Survey *Pub.* 38 (1933).

Oil and Gas Development in Mississippi

By B. C. Craft,* Baton Rouge, La.

(New York Meeting, February, 1934)

Oil and gas development in Mississippi during the year 1933 was rather active and a number of important wildcat wells were drilled throughout the state.

Mississippi showed an increase in drilling operations during 1933. There were 58 completions from 22 counties during this period, compared with 53 completions in 10 counties during 1932. The Jackson gas field in Hinds and Rankin counties continued to be the most active area with 26 completions, resulting in 17 gas wells, 2 oil wells, and 7 dry holes, compared with 38 gas wells, 1 oil well and 5 dry holes during 1932. A further attempt to extend the producing limits of the Amory gas field resulted in a dry hole.

Extensive exploration in south Mississippi has proved the existence of ample source beds and presence of an extensive sandbody near the top of Cockfield. Core tests, supplemented by extensive geophysical work, have been carried on in Jackson, George, Harrison, Pearl River and Stone counties. Exploration will be continued in 1934.

The most important deep test drilled in 1933, and the deepest well ever drilled in a southeastern state, was the Eastman Gardner et al., Bank of Seminary No. 1, sec. 26-8N.-15W., Covington County. This well went through about 1300 ft. of Selma chalk, and was abandoned in the Eutaw at 8004 ft. Another interesting operation during the past year was the Foster Creek Oil Corporation's Foster Creek Lumber Co. No. 1, sec. 14-2N.-2W., in the "Eastern Conroe Trend." This test is shut down at 3687 ft. in the Catahoula sandstone and has not encountered any important shows of oil or gas.

A total of 107 of the 117 gas wells completed in the Jackson gas field since its discovery in 1930 are still producing, and have a combined open flow of approximately 3,724,896,000 cu. ft. It is reasonable to assume that this area will be rather inactive during 1934 as the maximum daily production during 1933 was 3,476,000 cu. ft. The 10 wells that have gone dead were edge wells. The water level is now between the sub-sea depths of 2190 and 2195 ft. The Gulf Refining Company's Rainey No. 1, sec. 13-5N.-1E., one of the early wells in the field, had gas and water at −2225 ft. That the field is under hydraulic control is

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TABLE 1.—*Oil and Gas Production in Mississippi*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres: Oil	Gas	Total	Total Oil Production, Bbl.: To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Average Oil Production, Bbl.: Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933
1	Amory, *Monroe*..................	8	0	320	320							
2	Jackson, *Hinds, Rankin*..........	4	30	6,500	6,530	9,500	2,000	7,500	[1]	317	45	[2]
	Total........................		30	6,820	6,850	9,500	2,000	7,500				

Line Number	Total Gas Production, Millions Cu. Ft.: To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	Abandoned	At End of 1933: Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods at End of 1933, Number of Wells: Pumping	Gas-lift	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1932	1933
1	1,392	153	183	9	4	0	0	0		3	3	2,402	2,393			680	370	280
2	25,563	9,695	9,195	35	120	19	3	1	2	107	110	2,433	2,426	1	1	1,050	977	967
	26,955	9,848	9,377		124	19	3	1	2	110	113	2,432		1	1			

Line Number	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur Per Cent	Base[f]	Character of Gas, Approx. Average during 1933: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1						1,025	0	Hartselle	Mis	S	Por	8	MU	2	Fort Payne	3,045
2	13.6	13.6	13.6	1.8	A	931	0	Selma	CreU	C	Por	7	A	39	Igneous Rock	4,027
														41		

[b] Footnotes to column headings and explanation of symbols are on page 175.
[1] Wells are shut in the greater part of the time.
[2] Probably produce 50 barrels of oil and 1000 barrels of salt water.

indicated by the small decline in rock pressure. On the south edge of the field, sec. 14-15N.-1E., there are three wells capable of producing approximately 100 bbl. per day of heavy asphaltic-base crude with a high percentage of salt water. The crude contains no gasoline but makes good

TABLE 2.—*Summary of Drilling Operations in Mississippi*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934									Completed during 1933									Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes								Productive Wells	Dry and/or Near-dry Holes								Productive Wells		
	Total Depths, Ft.									Total Depths, Ft.										
	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	8000–9000	Total	(For Details, See Table 1)	500–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	8000–9000	Total	(For Details See Table 1)	Within Fields	Exploratory
Adams	0	0	1	0	1	0	0	2		0	0	0	0	0	0	0	0			0
Alcorn	0	0	1	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Attala	0	1	0	1	0	0	0	2		0	0	0	0	0	0	0	0			0
Bolivar	0	0	0	1	0	0	0	1		0	0	0	1	0	0	0	1			0
Calhoun	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Chickashaw	0	2	1	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Claiborne	0	3	0	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Clark	0	2	0	0	2	0	0	4		0	0	0	0	0	0	0	0			0
Clay	0	0	1	0	1	0	0	2		0	0	0	0	0	0	0	0			0
Copiah	0	2	2	0	0	0	0	4		0	0	0	0	0	0	0	0			0
Covington	1	1	0	3	2	0	1	8		1	1	0	1	0	0	1	4			0
Franklin	0	0	0	1	0	0	0	1		0	0	0	0	0	0	0	0			0
George	0	0	2	1	0	0	0	3		0	0	2	1	0	0	0	3			0
Greene	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			1
Grenada	0	0	1	0	1	0	0	2		0	0	0	0	0	0	0	0			0
Harrison	0	0	1	1	0	0	0	2		0	0	1	1	0	0	0	2			0
Hinds	0	4	22	10	2	2	0	40	55	0	1	1	1	0	1	0	4	9	0	1
Holmes	0	0	1	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Humphreys	0	0	0	1	0	0	0	1		0	0	0	0	0	0	0	0			0
Issaquena	0	0	0	1	0	0	0	1		0	0	0	0	0	0	0	0			0
Jackson	1	1	4	3	1	1	0	11		0	0	1	1	0	0	0	2			0
Jasper	0	0	1	1	0	1	0	3		0	0	0	0	0	1	0	1			0
Jefferson	0	1	2	0	0	0	0	3		0	0	0	0	0	0	0	0			0
Jefferson Davis	0	0	0	1	0	0	0	1		0	0	0	0	0	0	0	0			0
Jones	0	0	0	0	1	0	0	1		0	0	0	0	1	0	0	1			0
Lafayette	1	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Lamar	0	0	0	1	0	0	0	1		0	0	0	1	0	0	0	1			1
Lauderdale	0	0	2	4	0	0	0	6		0	0	0	0	0	0	0	0			0
Lea	1	0	0	1	0	0	0	2		0	0	0	0	0	0	0	0			0
Leake	0	0	0	1	0	0	0	1		0	0	0	0	0	0	0	0			0
Lincoln	0	0	1	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Lowndes	1	0	2	0	0	0	0	3		0	0	1	0	0	0	0	1			0
Madison	1	0	2	2	1	0	0	6		0	0	0	0	0	0	0	0			1
Marshall	0	0	2	1	0	0	0	3		0	0	0	0	0	0	0	0			0
Monroe	3	0	3	5	1	0	0	12	4	0	0	1	0	0	0	0	1	0	0	0
Montgomery	0	0	0	0	1	0	0	1		0	0	0	0	0	0	0	0			0
Neshoba	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Newton	1	0	1	0	0	0	0	2		1	0	1	0	0	0	0	2			1
Noxubee	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Panola	0	0	1	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Pearl River	0	0	1	1	0	0	0	2		0	0	1	1	0	0	0	2			0
Perry	0	0	0	1	0	0	0	1		0	0	0	0	0	0	0	0			0
Pike	0	0	1	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Rankin	1	0	12	7	3	0	0	23	65	0	0	3	0	0	0	0	3	10	0	3
Scott	1	0	0	0	0	1	0	2		1	0	0	0	0	0	0	1			0
Sharkey	0	0	0	2	0	0	0	2		0	0	0	0	0	0	0	0			0
Simpson	0	0	1	0	0	0	0	1		0	0	0	0	0	0	0	0			1
Smith	0	0	0	1	0	0	0	1		0	0	0	0	0	0	0	0			0
Stone	0	0	2	1	0	0	0	3		0	0	1	1	0	0	0	2			0
Sunflower	0	0	0	4	0	0	0	4		0	0	0	4	0	0	0	4			0
Tallahatchie	0	0	3	2	0	0	0	5		0	0	1	0	0	0	0	1			1
Tishomingo	0	1	1	0	0	0	0	2		0	0	0	0	0	0	0	0			0
Union	0	1	0	0	0	0	0	1		0	0	0	0	0	0	0	0			0
Warren	1	1	5	2	1	1	0	11		0	0	0	0	0	1	0	1			1
Washington	0	0	2	1	0	0	0	3		0	0	0	0	0	0	0	0			0
Wayne	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			1
Webster	0	2	0	0	0	0	0	2		0	1	0	0	0	0	0	1			0
Wilkinson	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0			1
Winston	0	0	1	1	0	0	0	2		0	0	1	0	0	0	0	1			0
Yalobusha	0	0	1	2	0	0	0	3		0	0	0	0	0	0	0	0			0
Yazoo	0	0	1	0	0	1	0	2		0	0	0	0	0	0	0	0			0
Total	13	25	85	65	18	7	1	214	124	3	3	15	13	1	3	1	39	19	0	13

gas oil and lubricating oil and has a high asphaltic content. These wells have been shut down the greater part of 1933.

Acknowledgments

The writer wishes to thank Mr. Garland Grigsby, Consulting Geologist, Shreveport, La., and Mr. Henry N. Toler of the Mississippi State Oil and Gas Board for information used in preparing this review.

Oil and Gas Development in Missouri in 1933

By F. C. Greene,* Rolla, Mo.

(New York Meeting, February, 1934)

Development work in western Missouri was continuous during 1933, owing to the shallow depths at which production is obtained and the low operating costs. Unfortunately, no statistics covering the total production of oil and gas during the year are available.

No new oil-producing pools were opened in 1933, but the Knoche area in T.46 N., R.33 W., Cass County, was extended. There are probably less than 100 producing oil wells, all in Cass and Jackson counties, with a combined production of possibly around 150 bbl. daily.

Several new gas areas were developed and there were several extensions of old areas, in 1933. Production was extended north by an entirely new pool—the Hammond pool, north of Plattsburg in Clinton Co. (sec. 18, T.55 N., R.31 W., and sec. 13, T.55 N., R.32 W.) where 13 wells were completed, the largest producing 2,332,000 cubic feet.

In the Bartle and Marshall pool in secs. 3-4-9-10, T.47 N., R.33 W., Jackson County, four wells opened a new area. The largest well was 1,000,000 cubic feet.

There were some small extensions near Independence, Jackson County.

Two wells of about 300,000 cu. ft. were completed at a depth of 700 ft. in Kansas City and in a deeper sand than is usually productive.

The Shaler area, in secs. 27–34, T.44 N., R.33 W. in Cass County, was extended with several wells, the largest of which was 300,000 cubic feet.

The production in the pools mentioned is obtained chiefly from the Henrietta and Cherokee formations of the Pennsylvanian age.

* Geologist, Missouri Geological Survey.

Oil and Gas Development in Montana during 1933*

By H. N. Hickey,† Great Falls, Mont.

(New York Meeting, February, 1934)

Wildcat drilling operations in Montana during 1933 did not yield any discoveries of oil or gas that were of major importance. There was comparatively little drilling in the older proven fields, as most of the interest was centered in the Cut Bank field, where 44 wells were completed. The total number of wells completed in the state during the year was 79, of which 62 were productive of either oil or gas.

Table 1.—*Oil and Gas Production in Montana*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres: Oil	Area Proved, Acres: Gas	Area Proved, Acres: Total
1	Bowdoin, *Phillips, Valley*	21		70,000	70,000
2	Hardin, *Big Horn*	20		2,000	2,000
	Cedar Creek, *Dawson, Prairie, Wibaux, Fallon*				
3	First sand	20	....	109,000	109,000
4	Second sand				
5	Elk Basin,[1] *Carbon*	18	140		140
6	Devil's Basin, *Musselshell*	14	*x*		100±
	Cat Creek, *Petroleum, Garfield*				
7	First sand	14	600		700
8	Second sand		250±		
	Soap Creek, *Big Horn*				
9	Amsden	13	600		600
10	Madison		*x*		*x*
	Kevin-Sunburst, *Toole*				
11	Gas field	12	*x*	50,000	50,000
12	Oil field	12	50,000	*x*	50,000
	Big Lake, *Stillwater*				
13	Eagle ss	12		1,500	1,500
14	Frontier ss	12		700	700
15	Dakota (?) ss	10	300		300
16	Boxelder, *Hill*	9		*x*	*x*
17	Bowes, *Blaine*	8		2,000±	2,000±
18	Cut Bank, *Glacier*	8	30,000±	30,000±	60,000±
	Whitlash, *Liberty*				
19	Colorado sands	7	*x*	4,000±	*x*
20	Upper Ellis ss		*x*	*x*	*x*
21	Pondera, *Pondera, Teton*	7	1,600		1,600
22	Bannatyne, *Teton*	7	1,000		1,000
23	Border,[2] *Toole*	5	450		450
	Dry Creek, *Carbon*	5			
24	Frontier ss			*x*	*x*
25	Greybull and Lakota ss		*x*		1,200±
26	Total		84,940±	269,200±	351,290±

[1] Larger part of field is in Wyoming.
[2] Extends across boundary into Alberta, Canada.

* Published by permission of G. C. Gester, chief geologist, Standard Oil Company of California.

† Geologist, The California Company.

Producing Fields

Bowdoin Gas Field.—The producing sands of this field are within the upper 500 ft. of the Colorado shale. In descending order they have been named the Martin, Bowdoin and Phillips sands. The Bowdoin sand is the principal gas-producing horizon and is about 300 ft. below the top of the Colorado shale.

Kevin-Sunburst Field.—The total area from which oil is being produced in the Kevin-Sunburst field is approximately 50,000 acres. Considerable portions of this area are untested and other parts of it have been found nonproductive, so the actual area from which oil is being obtained is indeterminate. Some oil is being produced from the Sunburst sand and the "stray" sand at the top of the Ellis formation but, from the available records, it is not possible to segregate this from the total production. The top of the Madison limestone is the principal producing horizon. Most of the porosity is found in a limestone, which is partly dolomitic, and in the form of small solution cavities.

The total area from which gas is being produced is approximately 50,000 acres but some parts of this area are unproductive because of an

Table 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil, Production, Bbl.		Total Gas Production, Millions Cu. Ft.		
	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Per Acre to End of 1933[b]	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933
1							1,216	316	218
2							202	53	49
3							37,465	4,935	5,065
4									
5	946,395	13,084	16,689	51	6,760	2			
6	36,000±	x	2,000±	7	x	3			
7	13,313,193	304,414	256,688	639	19,000	4			
8									
9	31,000±	x	6,000	0	x	0			
10									
11	x						24,675	2,064	1,985
12	27,135,531	1,326,646	1,178,115	3,478	x		x		
13							y	0	0
14							y	0	0
15	268,712	16,646	18,088	30	900	6			
16							578	151	427
17							3,441	454	361
18	308,628	22,787	285,590	1,181	x	32	9,918	3,966	4,502
19	14,000±			27	x	7	1,564	415	518
20									
21	3,207,080	417,103	343,994	874	2,000	6			
22	46,663	10,367	12,405	84	47	3			
23	512,417	160,525	86,975	205	1,140	10	x	x	x
24							1,877	814	556
25	487,779	188,413	120,879	697	x	100	y		
26	46,307,407	2,459,735	2,319,441	7,273			80,938	13,168	13,744

[b] Footnotes to column headings and explanation of symbols are on page 175.

unfavorable development of the Sunburst sand. The actual area from which the gas is being withdrawn cannot be determined definitely. Most of the gas is obtained from the Sunburst sand, near the base of the Kootenai formation. A few of the wells have found gas in the "stray" sand at the top of the Ellis formation.

Boxelder Gas Field.—The first well drilled on this structure was completed as a gas well in the Judith River formation but no gas has been produced from it. All the gas has been withdrawn from one well, which penetrated the Eagle sandstone only 4 feet.

Cut Bank Field.—Most of the oil and gas production comes from the Cut Bank sand at the top of the Ellis formation. A minor amount is produced from the Sunburst sand, near the base of the Kootenai formation. Three wells are producing gas from the Moulton sand, which is a lenticular sandstone in the Kootenai formation, above the Sunburst sand.

The areas of 30,000 acres each for the gas and oil fields are only rough approximations because of the limited amount of drilling that has been done. It is possible that the area that ultimately will be found to be productive will exceed these estimates considerably.

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933		Pressure, Lb. per Sq. In.[e]	Character of Oil, Approx. Average during 1933		
	Completed to End of 1933	During 1933		At End of 1933						Number of Wells			Gravity A.P.I. at 60°F.		
		Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Initial	Weighted Average	Sulfur Per Cent	Base[f]
1	32	1	0	11		21	32	750±	720			215			
2	22	0	0	0		22	22	730	700±			100			
3	152	1	1	91		60	151	900	830			210			
4								y	1,460			450			
5	22	0	0	y	22		22	1,530	1,490		22		40	0.1	P
6	5	1	0	3	2		5	1,180	1,175		2		25	1.6	M
7	210±	0	1	31	153		184	1,245	1,200		153		50	0.3	M
8								1,440	1,400				48	0.27	M
9	6	0	0	6	0		6	1,655	1,650		6		19	3.7	M
10								x	1,845				20	2.8	M
11	104	1	0	x	4	93	97	1,230	1,200		4	350	34	y	M
12	1,263	9	16	x	1,005	82	1,087	1,470	1,450		1,005		31	2±	M
13	9	0	0	8		0	8	1,195	1,170			260			
14	5	0	0	4		0	4	3,040	3,020			800			
15	7	0	0		5		5	3,850	3,830		5		44	y	P
16	2	0	0	1		1	2		1,272			315			
17	9	0	0	0		7	7	1,045	975			275			
18	74	42	1	4	38	31	73	2,835	2,800		38	725	39	0.72	M
19	12	2	0	3	4	4	11	1,420	1,400		4	280	40	y	P
20	0	0	0	0		1	1		2,065			650			
21	159	0	1	0	154		154	1,988	1,975		154		32	1.6	M
22	32	0	0	2	30		32	1,520	1,465		30		27	2.0	M
23	25	0	0	0	20	1	21	2,560	2,470		20		31	y	M
24	2	0	0	0		2	2	4,450	4,400			1,460 y			
25	9	1	0	0	8	1	9	5,525	5,500	8			52	0.02	P
26	2,161	58	20	164	1,445	326	1,935			8	1,437				

Whitlash Field.—Oil and gas are being obtained from three sands that occur in the lower 500 ft. of the Colorado shale. The area that has been proved for oil production is small but it has not yet been determined definitely. Only one well is producing gas from the upper Ellis sand and the producing horizon was penetrated only 3 ft., so the thickness of the sand at this location is not known.

TABLE 1.—(*Continued*)

Line Number	Character of Gas, Approx. Average during 1933		Producing Rock				Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933	
	B.t.u. per Cu. Ft.	Gal. Gasoline per M Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]			Name	Depth of Hole, Ft.
1	966	0	See text	Cre U	SH	Por	D	14	Madison (?)	3,180
2	y	0	Frontier	Cre U	S	Por	MF(?)	0	Kootenai	2,210
3	943	0	Judith River	Cre U	S	Por	A	42	Lakota	4,187
4	y	0	Eagle (?)	Cre U	SH	Por	A			
5			Frontier	Cre U	S	18	D		See Wyoming	
6			Quadrant	Mis	S(?)	y	[s]	27	Madison	2,505
7			First Cat Creek	Cre U(?)	S	Por	D	109±	Madison	4,124
8			Second Cat Creek	Cre L	S	Por	[s]			
9			Amsden	Pen	S(?)	Por	D	7	Madison	1,964
10			Madison	Mis	L	y	D			
11	1,026	0	Sunburst	Cre L	S	Por	[s]	37	Pre-Cambrian (?)	4,710
12	y	0	Madison	Mis	L, D		[s]	658		
13	y	0	Eagle	Cre U	S	Por	D	11	Lakota ss.	4,043
14	y	0	Frontier	Cre U	SH	Por	D			
15			Dakota (?)	Cre L(?)	S	Por	D	7		
16	y	0	Eagle	Cre U	S	Por	A	0	Eagle	1,276
17	930y	0	Eagle	Cre U	S	Por	D	1	Madison	4,700
18	y	0.3	See text		S	14	MC	4	Madison	2,978
19	956	0	See text	Cre U	SH	Por	D	10	Madison	2,110
20	y	0	Upper Ellis	Jur	S	Por				
21			Madison	Mis	L, D	Por	T	14	Madison	2,354
22			Bannatyne	Jur	SH	Por	D	8	Madison	1,565
23	y	0	Vanalta	Jur	S, SH	Por	MC	11	Madison	2,645
24	1,085	0	Frontier	Cre U	S	Por	AF	1	Tensleep	6,887
25			Greybull and Lakota	Cre L	S	Por	AF			

[s] Dome with accumulation localized by change in character of stratum.

TABLE 2.—*Summary of Drilling Operations in Montana*

County	Completed Prior to Jan. 1, 1934									Completed during 1933						Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes								Productive Wells (For Details See Table 1)	Dry and/or Near-dry Holes					Productive Wells (For Details See Table 1)		
	Total Depths, Ft.									Total Depths, Ft.							
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	Total		1000–2000	2000–3000	3000–4000	5000–6000	Total		Within Fields	Exploratory
Beaverhead	1	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Big Horn	4	9	11	1	0	0	0	25	27	0	0	0	0	0	0	0	1
Blaine	2	2	2	0	2	0	0	8	8	0	0	0	0	0	0	0	0
Broadwater	1	1	1	0	0	0	0	3	0	0	1	0	0	1	0	0	0
Carbon	14	18	7	2	2	0	1	44	33	1	0	0	0	1	1	1	2
Carter	2	3	2	1	0	0	0	8	0	0	0	0	0	0	0	0	0
Cascade	5	13	4	3	0	0	0	25	0	0	0	0	0	0	0	0	1
Choteau	1	5	10	0	0	0	0	16	1	0	0	0	0	0	0	0	0
Custer	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Daniels	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	1
Dawson	3	1	0	0	1	0	0	5	11	0	0	0	0	0	0	0	0
Fallon	7	12	3	1	1	0	0	24	131	0	0	0	0	0	1	0	0
Fergus	15	18	9	4	0	0	0	46	1	0	1	0	0	1	1	0	2
Flathead	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Gallatin	2	0	1	0	0	1	0	4	0	0	0	0	0	0	0	0	3
Garfield	0	14	1	1	1	0	0	17	4	0	0	0	0	0	0	0	0
Glacier	2	3	4	4	1	0	0	14	73	0	3	0	0	3	42	18	1
Golden Valley	3	3	8	1	0	0	0	15	0	0	0	1	0	1	0	0	0
Hill	21	5	0	2	0	0	0	28	3	0	0	0	0	0	1	0	1
Judith Basin	4	7	1	0	0	0	0	12	0	1	0	0	0	1	0	0	0
Lake	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Lewis and Clark	5	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Liberty	1	4	15	6	0	0	0	26	17	0	0	0	0	0	2	1	3
Musselshell	10	18	8	1	0	0	0	37	3	1	0	0	0	1	1	0	1
Park	1	0	1	1	0	0	0	3	0	0	0	0	0	0	0	0	0
Petroleum	19	156	6	3	1	0	0	185	184	1	0	0	0	1	0	0	2
Phillips	7	3	4	1	0	0	0	15	25	0	0	0	0	0	1	0	2
Pondera	0	11	19	3	1	0	0	34	146	0	0	0	0	0	0	0	0
Powder River	2	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Powell	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Prairie	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Ravalli	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Richland	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Roosevelt	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Rosebud	1	7	3	2	1	0	0	14	0	0	0	0	0	0	0	0	1
Stillwater	2	13	4	11	6	0	0	36	19	0	0	0	0	0	0	0	0
Sweetgrass	1	2	1	1	0	1	0	6	0	0	0	0	1	1	0	0	0
Teton	4	35	21	6	0	0	0	66	40	0	0	1	0	1	0	0	2
Toole	3	874	49	6	2	0	0	934	1206	3	0	0	0	3	11	5	3
Valley	1	3	0	0	0	0	0	4	4	1	0	0	0	1	0	0	0
Wheatland	1	5	2	0	1	0	0	9	0	0	0	0	0	0	0	0	0
Wibaux	3	0	0	0	0	0	0	3	7	0	0	0	0	0	0	0	0
Yellowstone	14	13	10	6	1	0	0	44	1	0	0	1	0	1	1	0	0
Total	168	1262	210	68	22	2	1	1733	1944	8	5	3	1	17	62	25	26

Oil and Gas Development in New Mexico

By C. E. Shoenfelt* and Dean E. Winchester,† Denver, Colo.

(New York Meeting, February, 1934)

No important discoveries of petroleum during 1933 were reported from New Mexico. Lea and Eddy counties were the centers of activity during the drilling season and each had a number of interesting completions. The Hobbs pool, in Lea County, was definitely outlined on the east, north and northwest.

Under an agreement reached last summer by state officials and operators, the Hobbs pool was continued under proration throughout the year. One hundred eighty-four units of 40 acres each were being produced at the end of 1933. The allowable was 21,306 bbl. daily at the beginning of 1933, but when the agreement was revised in the spring the minimum was raised to 30,000 bbl., and by the end of the year had been raised to 33,473 bbl. At present the field is being prorated on the basis of 25 per cent on acreage and 75 per cent on potentials except in the southwestern edge of the field, where water encroachment is a problem. In this area the basis of proration is 40 per cent on acreage and 60 per cent on potentials. A corrective method employed in this part of the field has been partly successful. The water is advancing in the upper part of the pay, a dolomitic limestone, and in a number of instances packers have been set in the pay below the water and above the oil. The locating of a satisfactory seat for a packer is difficult and in some instances has not been a complete success.

Pipe line runs from the field during the year aggregated 11,413,218 bbl., bringing the total gross production up to 41,093,681 bbl., of which 39,000,000 bbl. has been produced under proration, which went into effect on July 10, 1930. On Nov. 30, potentials were determined on the assigned pressure basis and the total was reduced 71,165 bbl. daily, to 1,265,332 barrels.

The outstanding completions in the Hobbs pool were three in number, of which the best was the Humble Oil & Refining Company's No. 3B Bowers in sec. 20, 18S., 38E., with an initial production of 11,664 bbl. of oil and 10,000,000 cu. ft. of gas. The Shell Petroleum Company's No. 4B McKinley, in the same section, produced at the rate of 22,940 bbl. of oil while flowing open, but when tubed, flowed at the rate of 6610 bbl. The third outstanding well, No. 4 Hardin of the Tidal Oil Co., and located in

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TABLE 1.—*Oil and Gas Production in New Mexico*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres, Oil	Total Oil Production, Bbl.: To End of 1933	Total Oil Production, Bbl.: During 1932	Total Oil Production, Bbl.: During 1933	Total Oil Production, Bbl.: Daily Average during Nov., 1933
1	Artesia, *Eddy*	9	3,000	3,889,521	177,890	200,552	597
2	Caprock, *Eddy*	7	1,500	1,181,057	291,176	399,318	1,326
3	Cooper, *Lea*	3	600	76,869[1]	37,435	29,434	119
4	Eunice, *Lea*	5	1,000	1,012,650	175,781	289,489	1,117
5	Getty, *Lea*	5	320	148,182	0	0	0
6	Hobbs, *Lea*	5	6,280	41,093,681	10,101,515	11,413,218	34,014
7	Hogback, *San Juan*	10	700	1,452,347	130,459	77,017	211
8	Hospah, *McKinley*	6	160	5,980	0	0	0
9	Jal, *Lea*	5	1,000	1,821,706	344,474	547,930	1,942
10	Lea, *Lea*	3	640	4,277,944	788,694	801,288	2,058
11	Rattlesnake, *San Juan*	10	600	2,734,252	245,584	262,026	824
12	Table Mesa, *San Juan*	8	320	342,488	27,458	29,130	95
	Total		16,120	58,036,677	13,320,466	14,040,402	

[1] Prior to 1932 included with Jal.

Line Number	Average Oil Production, Bbl.: Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone
1	1,296		3+	325	9	3		186	25	211	2,343	
2	787		63	40	0	0		21	0	21	3,000	
3	128[1]		30	10	0	0		4	0	4	3,757	
4	1,013		93	19	1	1		12	0	12	4,087	
5	463		0	13	0	0	3	0	0	0	1,367	
6	6,543		176	201	20	1		193	0	193	4,240	
7	2,075	138	35	15	0	0		6	0	6	742	727
8	35	3.5	0	12	0	1	4	0	0	0	1,804	1,794
9	1,822		13	33	5	0		19	0	19	3,320	
10	6,681		187	13	3	1		11	0	11	3,700	
11	4,557	75	45	30	1	0		18	0	18	796	735
12	1,070	153	16	13	0	0	0	6	0	6	1,335	1,328
				724	39	7	7	476	25	501		

[b] Footnotes to column headings and explanation of symbols are on page 175.

Line Number	Oil Production Methods at End of 1933, Number of Wells: Flowing	Pumping	Character of Oil Approx. Average during 1933: Gravity A.P.I. at 60° F., Weighted Average	Sulfur, Per Cent	Base[f]	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1	0	186	37	0.87	M	Dolomite zone	Per	D	Fis		D	114		
2	0	21	36	1.09	M	Dolomite zone	Per	D	Fis		D	19		
3	0	4	35	y	M	Carlsbad	Per	L	Fis		?	6		
4	0	12	27	1.65	M	Carlsbad	Per	L	Fis		D	7		
5	0	0	21	1.20	A	Carlsbad	Per	L	Fis		D	10		
6	193	y	27.5	1.05	M	Carlsbad	Per	L	Fis		D	8	San Andres	
7	0	6	56	0.00	P	Dakota	Cre U	S	y	15	D	9		
8	0	0	27	0.15	M	Mesa Verde	Cre U	S	s	10	D	8	Dakota (Cre U)	3,282
9			37.5	1.97	A	Carlsbad	Per	L	Fis			14		
10			27.5	1.53	M	Carlsbad	Per	L	Fis			2		
11	0	18	64.8	0.04	P	Dakota	Cre U	S	y	61	D	12	Goodrich (Pen)	7,370
12	0	6	58	0.04	P	Dakota	Cre U	S	y	7	D	7		

TABLE 2.—*Summary of Drilling Operations in New Mexico*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934 — Dry and/or Near-dry Holes — Total Depths, Ft.									Completed Prior to Jan. 1, 1934	Completed during 1933 — Dry and/or Near-dry Holes — Total Depths, Ft.							Completed during 1933	Drilling or Incomplete at End of 1933	
	0-1000	1000-2000	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000	Total	Productive Wells (For Details, See Table 1)	0-1000	1000-2000	2000-3000	3000 4000	4000-5000	5000 6000	Total	Productive Wells (For Details, See Table 1)	Within Field	Exploratory
Bernalillo	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	1
Catron	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Chaves	14	16	14	7	3	2	0	0	56	0	0	0	1	0	0	0	1	0	0	1
Colfax	1	2	3	1	2	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
Curry	4	2	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
De Baca	8	2	0	2	3	0	0	0	15	0	0	0	0	0	1	1	2	0	0	0
Dona Ana	3	1	0	1	0	0	0	0	5	0	1	0	0	0	0	0	1	0	0	0
Eddy	31	33	325	64	6	1	0	0	460	232	0	0	12	0	0	0	12	12	4	10
Guadalupe	3	2	3	1	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	2
Harding	2	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Hidalgo	2	2	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Lea	8	3	3	302	32	13	0	0	361	239	0	0	0	9	21	2	29	29	4	0
Lincoln	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Luna	0	0	3	2	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	3
McKinley	35	27	4	4	0	0	0	0	70	12	0	1	0	0	0	0	1	0	0	0
Mora	0	2	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Otero	1	2	1	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Quay	1	1	0	6	1	1	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Rio Arriba	4	9	4	1	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	2
Roosevelt	1	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Sandoral	2	1	3	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	14
San Juan	73	37	8	6	0	0	0	0	124	58	4	0	0	0	0	0	4	0	0	4
San Miguel	10	6	3	1	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	1
Santa Fe	1	1	2	2	0	0	0	0	6	0	1	0	0	0	0	0	1	0	0	0
Sierra	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Socorro	3	4	1	2	1	0	0	0	11	0	0	0	0	0	0	0	0	0	0	1
Torrance	6	10	1	4	0	1	0	0	19	0	0	0	0	0	0	0	0	0	0	0
Union	4	0	4	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	2
Valencia	0	3	2	3	4	1	1	0	14	0	0	0	0	0	0	1	1	0	0	
Total	217	167	388	410	56	20	1	1	1257	541	6	1	13	9	22	5	53	41	8	43

sec. 19, 18S., 38E., had an initial production of 6026 bbl. of oil and 5,239,000 cu. ft. of gas.

Four wells were drilled in the Lea area, one by Cranfill & Reynolds and three by the Texas Co., one of which was dry and limits the productive area on the northwest. One of the Texas Company's wells, a near-dry hole, was treated with acid twice and was finally completed with an initial production of 310 bbl. of oil and 100 bbl. of water.

The outstanding development in the Jal area was the Continental Oil Company's No. 1B Sholes in the SW.NW. corner of sec. 13, 25S., 36E., which had an initial production of 2280 bbl. of oil with 40,000,000 cu. ft. of gas in limestone at 3370 ft. This well holds the record for size in the Jal pool and was the cause of considerable activity in that area, which was just getting under way at the close of the year.

ACKNOWLEDGMENT

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Oil and Gas Development in New York State

By D. H. Newland,* Albany, N. Y.

(New York Meeting, February, 1934)

On the bulk basis New York's contribution to the production of oil is small, representing, as it does, a bare half of one per cent of the annual total for the United States. Yet it has more importance than is implied by such a statement. Petroleum includes a variety of organic compounds, some more and some less valuable. It would be a fairer estimate of the situation to say that New York in recent years has produced around 10 to 12 per cent on the average of all Pennsylvania grade oil, the supply of which is strictly limited and the demand steady even in times of overproduction of other grades.

One may not infer from this that New York and other Appalachian states enjoy an independent position in the market with a price structure uninfluenced by that of the Mid-Continent, Gulf or California fields. On the other hand, the recent market demoralization in the South and West brought about by uncontrolled production caused prices to drop to a point where the life of the local industry was seriously threatened.

The current cost of producing oil in New York under the methods of water-flooding, by which most of the output is now obtained, has been estimated by competent authority at not less than $2.50 a barrel. The

Table I.—*Oil and Gas Production in New York State*

Line Number	Field, *County*	Age, Years to End of 1933	Area proved, Acres		Total Oil Production, Bbl.				Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.	
			Oil	Gas	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov. 1933	During 1932	During 1933
1	Allegany, *Allegany and Steuben*	54	30,000		67,665,113	2,580,019	2,366,964	6,602	2,250±	102±	0.441		
2	Bradford Extension, *Cattaraugus*	57	25,000		28,*xxx*,*xxx*	927,981	789,*xxx*	2,2*xx*	1,1*xx*	5*x*	0.8		
3	Gas production in 14 counties			*y*								8,*xxx*	8,*xxx*
	Total		55,000	*y*	96,*xxx*,*xxx*	3,508,000	3,156,*xxx*	8,8*xx*				8,*xxx*	8,*xxx*

[b] Footnotes to column headings and explanation of symbols are on page 175.

* State Geologist of New York.

average yield is put at 4000 bbl. to the acre. With the use of the most improved methods of well drilling and lease operation the cost may be reduced to somewhat below that figure. It is apparent that with Pennsylvania grade selling at under $2.00 a barrel, as it did in 1933, the producers had to submit to very substantial losses which if continued over a considerable stretch of time would involve the ruin of the business.

Price will be the governing factor in future production. Under profitable operative conditions the life of the fields may be prolonged for 25 years at least. The output, however, is not likely to be raised much above the present rate even in the best circumstances.

In 1933 there were about 17,600 wells in Cattaraugus, Allegany and Steuben counties, of which, perhaps, 5000 were employed on water-flooding and the rest strippers. Allegany County alone had about 15,000 wells. This county has accounted for two-thirds of the total yield of 96,000,000 bbl., accredited to New York up to the close of 1933.

There is little prospect of materially enlarging the present productive fields lying on the Pennsylvania border. It is 25 years or more since any considerable extension of the acreage has taken place. The present proved area is about 55,000 acres. It is still an open question whether oil in quantity may not be found somewhere below the Chemung sands, but thus far only inconsiderable production has been obtained from such sources. The few deep tests in southwestern New York can hardly be taken as conclusive evidence on that point. There is added incentive to the exploration of the underlying formations by reason of the possible presence of natural gas, especially in the Oriskany and Medina sandstone. A test recently made in Allegany County encountered the Oriskany at

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells					Average Depth, Ft.		Oil Production Methods at End of 1933		Pressure, Lb. per Sq. In.[e]			Character of Oil, Approx. Average during 1933				
	Completed to End of 1933	During 1933		At End of 1933		Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Initial	Average at End of		Gravity A.P.I. at 60°F.			Sulfur, Per Cent	Base[f]
		Completed	Abandoned	Producing Oil Only	Producing Gas Only			Pumping	Injection into Reservoir[d]		1932	1933	Maximum	Minimum	Weighted Average		
1	y	295[1]	163[1]	14,952		1,300–1,500	1,200–1,400	14,952	W[2]	300±	10±	10±	45.6[4]	38	42.4	0.10	P
2	y			2,500		900–1,500	850–1,400	2,500	W[3]				47[5]	38	43	0.10	P
3	y				y			17,452									
	y			17,452	y												

[1] Oil wells.
[2] Approximately 4000 injection wells.
[3] Approximately 1000 injection wells.
[4] Scio.
[5] Chipmunk.

about 4500 ft. but found little gas or oil. In Cattaraugus County a test well was drilled to the Medina at 6250 ft.; a moderate quantity of gas was reported.

Most of the natural gas produced in New York State for general consumption, about 8,000,000 M. cu. ft. annually on the average, is obtained from a number of fields outside of the oil district. Altogether 14 counties situated in the central and western parts share in the output. The principal productive horizon is the Medina, which underlies practically all the interior from Lake Ontario, where the sandstone outcrops, to the Pennsylvania state line, where it is encountered at depths of 5000 ft. or more. The discovery of natural gas in the Oriskany sandstone in 1930 has been productive of active exploration, particularly in the region of the Finger Lakes, but thus far the Tyrone field, situated between Seneca and Keuka lakes in Schuyler, Steuben and Yates counties and covering about 6000 acres, remains the single substantial producer from that formation.

Table 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1933		Producing Rock					Structure[j]	Deepest Zone Tested to End of 1933	
	B.t.u. Per Cu. Ft.	Gals. Gasoline Per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.		Name	Depth of Hole, Ft.
1	1,150	2.5±	Richburg, Fords Brook, Penny, Scio, Fulmer Valley, Waugh and Porter, Clarksville, Nile							
2				Dev.	S	16	20–24	H	Oriskany sandstone	4,500
3			Bradford, Chipmunk, Rice Brook	Dev.	S	15	20	H	Medina sandstone	6,250

Petroleum Development in Oklahoma in 1933

By L. G. E. Bignell,* James O. Lewis† and E. A. Hanson,‡ Tulsa, Okla.

(New York Meeting, February, 1934)

There was a general upward trend of all petroleum activities in Oklahoma during 1933, especially in the last quarter, though the average price for crude oil for the year was below 1932 and overproduction in East Texas demoralized conditions for several months. As the Federal Agencies established under the National Industry Recovery Act began to function conditions in Oklahoma were visibly affected and production of "hot oil" from Oklahoma City field practically ceased.

More oil wells were completed, six new fields discovered, extensive geophysical prospecting carried on in many parts of the state, and an increased amount of clean-out and reconditioning work done in older pools during the past year. To increase quantity and rate of recovery of oil many wells producing from limestone formations were treated with hydrochloric acid.

The Oklahoma City field had a reported production of 66,984,570 bbl. of oil during 1933, or almost exactly twice the amount reported for 1932. Potential tests and other indicators show that the wells are rapidly approaching the stage where mechanical lift must be applied to all of them, including the wells in the Wilcox sand zone.

The major pipe-line companies serving the oil fields of Oklahoma have been anxious to make connections to all wells during 1933 and have indicated a willingness to accept all oil available. The amount offered has been restricted by proration orders, but the state did produce 178,356,449 bbl. during the year, an increase of about 18.6 per cent over 1932. This increase was practically all due to the greater demand for Oklahoma City oil, as all other pools of any importance showed loss in production or very small gains last year. The U. S. Bureau of Mines' laboratory reports the lubricating distillate content of Oklahoma City crude from Arbuckle and Lower Simpson formations about 17 per cent by volume. East Texas oil is reported to contain about 5.6 per cent lubricating distillates.

The desire of the transportation companies to keep their equipment operating at maximum capacity and the need of some refineries for more

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oil has tended to stimulate the reconditioning of old wells in eastern and southern Oklahoma. This movement was well under way in 1933 and it seems evident that activity in this direction will increase as the available oil from Oklahoma City decreases in quantity.

Prices

The price for 36° gravity crude has varied from 69¢ per barrel in January, down to 25¢ in May, 1933 and closed at $1.00 per barrel, the price posted in September. With the demand for Oklahoma grade crude oil continuing steady and the available supply growing less the local situation is favorable for good prices. Average price for 1933 for 36° gravity oil was 65¢, compared with 88¢ average for 1932.

Completions

There were fewer completions in 1933 than in 1932, the totals being 1093 and 1130 respectively, but there were 668 new oil wells completed in 1933 as against 643 oil wells in 1932. The relation of oil wells to total completions is 62 per cent for 1933 and 56.8 per cent in 1932. The wells completed in 1933 are reported to have an initial average production of 460.1 bbl. daily while those completed in 1932 averaged 1006.7 bbl. daily initial production. This indicates the need for an increase in the number of oil wells.

New Pools

Of the new fields discovered in Oklahoma in 1933, none appear to be important in size, but all hold possibilities of containing much needed crude oil reserves. Probably the most important discovery was the Crescent pool, in Logan County about 54 miles north of Oklahoma City. The first well was completed by Gypsy Oil Co. and Carter Oil Co. and rated at 5000 bbl. per day initial. Six wells were completed during the year.

In the Greater Seminole district two new pools were opened: Sasakwa Townsite and Keokuk Falls pools. The discovery well completed in Sasakwa Townsite pool by Stanolind Oil and Gas Co., Amerada Petroleum Corpn. and Indian Territory Illuminating Oil Co. flowed 2525 bbl. per day from Wilcox sand at 4040 to 4051 feet.

The Keokuk Falls field is about 5 miles north of the Searight field. The discovery well was drilled by Carter Oil Co., Gypsy Oil Co. and Sinclair Prairie Oil Co. and found oil in the Misener sand at 4090 to 4106 ft. Initial gage was 2327 bbl. per day.

A new field was opened by Magnolia Petroleum Co. in Lincoln County, which is now known as the West Chandler field to distinguish it from the original pool just west of that city. It gaged 663 bbl. in 14 hr., and 1180 bbl. in 24 hr. from Wilcox sand found at 4982 to 4988 feet.

In Creek County there were 187 completions during 1933, of which 117 were oil wells. The Olive pool was opened by J. E. Crosbie's No. 1 Escoe in sec. 26-18-8, making 100 bbl. per day from the Layton sand at 1313 to 1345 feet.

The sixth pool opened in Oklahoma last year is known as the Fitts pool, named for John Fitts, geologist, of Ada, Okla., who mapped the structure in Pontotoc County where E. H. Moore and others found oil at 2640 to 2641 ft. There being no outlet for the oil when the well was completed, it was shut in until December, when it made 700 bbl. of oil in 50 hours.

The Lucien pool, discovered in 1932 in Noble County, and the Naval Reserve area in Osage County, have received considerable attention during 1933. All areas having showings of oil have been consistently drilled during the past year, with the amount of work increasing after oil reached the $1.00 posted price in September.

Oil and Gas Development in Pennsylvania

By George H. Fancher,* State College, Pa.

(New York Meeting, February, 1934)

Improving economic conditions are reflected in the statistical picture of the petroleum and natural gas industry for 1933. Prices were better, demand was greater and the volume of production increased.

The increase in the production of gas has been due mainly to the utilization of outlets to the new prolific gas fields of Potter and Tioga counties; of oil, to the growing demand for Pennsylvania grade lubricants. It should be emphasized that nowhere is volume of production more subject to control due to the extensive use of secondary methods of recovery and regional peculiarities than in Pennsylvania.

A summary of developments in production for Pennsylvania in 1933 of necessity is brief. The data listed in Table 1 are all too few in number and not all that is desirable from the standpoint of accuracy. No state agency for the collection of data exists, no reports are compulsory. Nevertheless, because of the hearty cooperation of many individuals and public spirited corporations, it is believed that the data are as reliable as are obtainable at the present time. Furthermore, records of the past too often are lost, were never in existence or are fragmentary, to say the least. Illustrative of the condition is the fact that no thorough study of the oil and gas-producing regions has ever been made.

The publications of the Pennsylvania Topographic and Geologic Survey upon the subject are noteworthy and valuable, especially the most recent one.[1] The Survey has been handicapped in the work by lack of time, personnel and funds in addition to the difficulties mentioned previously.

It is obvious, therefore, that Table 1 cannot be completed for Pennsylvania. The data simply are not in existence. Officially there are 328 oil and gas pools or fields known by name and 58 distinct sands or horizons, one or more of which are productive of oil and gas in the various pools, but reliable data for only three general regions could be assembled.

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[1] J. D. Sisler, G. H. Ashley, F. T. Moyer and W. O. Hickok, 4th: Contributions to Oil and Gas Geology of Western Pennsylvania. Pennsylvania Geologic Survey, 4th Ser., *Bull.* M19 (1933).

Appalachian Geosyncline

This is not so alarming as it appears to be because the oil and gas-producing region of Pennsylvania (in fact, the whole Appalachian region) may be considered as a geologic entity; namely, the Appalachian geosyncline.

It is definitely established that accumulation within this area has been controlled only to a limited extent by structure in the majority of cases and largely by local sand conditions; namely, the resultant porosity, permeability and thinning and thickening of sediments due to original manner of deposition and subsequent alteration.

The general recognition of these facts is producing dividends in certain areas as a result of intensive study of local sand conditions by means of reconnaissance, core analysis, the intensive development of likely and

Table 1.—*Oil and Gas Production in Pennsylvania*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Bradford	63	70,xxx		70,xxx	252,422,xxx	9,244,xxx	9,350,xxx	28,650
2	*McKean*								
3	Kane to Butler		358,xxx		358,xxx		2,178,xxx	2,267,xxx	5,950
4	*McKean*		24,xxx		24,xxx		148,xxx		
5	*Warren*		49,xxx		49,xxx		308,xxx		
6	*Crawford*		14,xxx		14,xxx		98,xxx		
7	*Mercer*		11,xxx		11,xxx		14,xxx		
8	*Venango*		84,xxx		84,xxx		1,027,xxx		
9	*Forest*		22,xxx		22,xxx		94,xxx		
10	*Elk*		8,xxx		8,xxx		81,xxx		
11	*Lawrence*		14,xxx		14,xxx		21,xxx		
12	*Butler*		105,xxx		105,xxx		387,xxx		
13	*Clarion*		27,xxx		27,xxx				
14	Southwest Pennsylvania		203,xxx		203,xxx		990,xxx	1,022,xxx	2,650
15	*Butler*		39,xxx		39,xxx		140,xxx		
16	*Beaver*		18,xxx		18,xxx		48,xxx		
17	*Allegheny*		66,xxx		66,xxx		250,xxx		
18	*Washington*		55,xxx		55,xxx		380,xxx		
19	*Greene*		25,xxx		25,xxx		172,xxx		
20	Farmington								
21	*Tioga*	3		4,800	4,800				
22	Hebron	2		5,000	5,000				
23	*Potter*								
24	Miscellaneous Gas Fields								
25	*Armstrong*								
26	*Clearfield*								
27	*Erie*								
28	*Fayette*								
29	*Indiana*								
30	*Jefferson*								
31	*Potter*								
32	*Westmoreland*								
33	Total		631,xxx	9xx,xxx	1,5xx,xxx	878,614,xxx	12,412,xxx	12,639,xxx	37,250

the elimination of poor acreage even in territory long productive of oil and gas.

The first region listed in Table 1 is the Bradford field, which is a unique structural and productive unit from many points of view. A considerable literature is available concerning the field and its operations. Water-flooding is employed on a large and successful scale in the Bradford field and accounts for the substantial relation its production bears to the total for the state. No noteworthy improvements in the technique of its application have been made during the past year, although it is believed that there has been evidence of a more general realization of the part that engineering can play in changing loss to profit.

The approximate productive area of the Bradford field is 85,000 acres, of which about 15 per cent is in New York State. Table 1 contains

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.			Number of Oil and/or Gas Wells					
								During 1933		At End of 1933		
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov. 1933	To End of 1933	During 1932	During 1933	Completed to End of 1933	Completed	Abandoned	Producing Oil only	Producing Gas only	Total Producing
1												
2	3,600	90	0.98		2,255	2,255		752		30,xxx		
3			0.13					118		44,5xx		
4												
5					475	475				6,xxx		
6										1,xxx		
7					114					38x		
8					2,044					25,xxx		
9					483					1,5xx		
10					2,949					1,xxx		
11					14					7xx		
12					1,000					4,xxx		
13					8,308					2,5xx		
14			0.39					45		6,8xx		
15					372					1,5xx		
16					190					7xx		
17					2,824					1,5xx		
18					7,058					1,7xx		
19					8,979					7xx		
20												
21				14,655	3,317	7,547	87	4	1		40	40
22												
23				3,739	453	2,836	24	16	9		15	15
24					7,554							
25												
26					436							
27					7							
28					1,421							
29					1,168							
30					6,649							
31					1,805							
32					2,541							
33			0.43	4,672,xxx	62,416	65,xxx	190,xxx	935		81,3xx	16,628	

[b] Footnotes to column headings and explanation of symbols are on page 175.

data for only the portion of the field that lies within Pennsylvania. It is estimated, based on an average recovery by the methods now in use of approximately 5000 bbl. per acre, that approximately 20,000 acres within the state have been depleted, leaving some 59,000 acres yet to be developed. However, an estimate of marginal territory might reduce this to some 44,000 acres of good territory. Furthermore, a certain percentage of the production comes from unflooded naturally produced wells to which water-flooding may never be applied.

The average saturation in the field in territory untouched by water is perhaps 60 per cent. This opinion is founded upon the results of core analysis. At the present rate of production the field should have a life of from 20 to 25 years based upon prevalent recoveries. The field is 63 years old and some wells have produced oil steadily for over 45 years. One engineer has estimated that 30 per cent of the original

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods At End of 1933			Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1933			
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells		Injection into Reservoir[d]	Initial	Average at End of		Gravity A.P.I. at 60° F.		Sulfur, Per Cent	Base[f]
			Flowing	Pumping			1932	1933	Maximum	Minimum		
1												
2	1,700	1,660		29,326	W	600	30	30	46.5	43.4	0.14	P
3				44,502								
4							*y*	*y*	46.5	40.4	0.1*x*	P
5	600	580		6,*xxx*			*y*	*y*	45.4	42.3	0.15	P
6				1,*xxx*			*y*	*y*				P
7				38*x*			*y*	*y*	32.5	32.5	0.09	P
8	750	730		25,*xxx*	GA		vac.	vac.	41.5	31.7	0.11	P
9	750	730		1,5*xx*			*y*	*y*				P
10				1,*xxx*			*y*	*y*				P
11				7*xx*			*y*	*y*				P
12	1,200	1,185		4,*xxx*			vac.	vac.	46.9	45.4	0.12	P
13				2,5*xx*			vac.	vac.				P
14				6,838								
15	1,505	1,490		1,5*xx*			vac.	vac.	46.9	45.4	0.12	P
16				7*xx*			vac.	vac.				P
17	2,100	2,050		1,5*xx*			vac.	vac.	45.4	41.7	0.14	P
18	2,200	2,150		1,7*xx*			vac.	vac.	52.0	43.2	0.1*x*	P
19	2,200	2,150		7*xx*			vac.	vac.	40.4	40.4	0.08	P
20												
21	4,050	4,040				1,650	1,280	900				
22												
23	4,885	4,880				2,150	2,1*xx*	2,000				
24												
25							*y*	*y*				
26							*y*	*y*				
27							*y*	*y*				
28							*y*	*y*				
29							*y*	*y*				
30							*y*	*y*				
31							*y*	*y*				
32							*y*	*y*				
33				80. *x*,*x*,*x*								

oil in the field has been recovered by natural methods of recovery and that 10 per cent more will be recovered by water-flooding. Two interesting deductions may be made from this opinion: (1) a vast volume of oil (60 per cent of that originally present) is unrecoverable by the prevailing methods and stands as a challenge to the ingenuity of the research engineer, and (2) the original saturation in the field was about 85 per cent. These statements apply only to the third Bradford sand.

A reserve of some importance apparently exists in the fourth Bradford or Windfall sand within the limits of the Bradford field. Information concerning it is meager; it is not known with certainty whether it is continuous throughout the field because relatively few wells are drilled to it. In some localities, however, it lies approximately 100 ft. below the third Bradford, is about 30 ft. thick and carries a 65 per cent saturation of oil. A reliable estimate of its potentialities cannot be ventured at this time.

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1933		Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested To End of 1933	
	B.t.u. per Cu. Ft.	Gals. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Feet			Name	Depth of Hole, Ft.
1											
2	1,150	25	3rd Bradford	Dev U	S	12.5	40	A	1,398	Red Medina	5,760
3									18,271		
4			See text	Dev U	S			AMC			
5		20	See text	Dev U	S	15.0	20	AMC		Queenston shale	5,818
6			See text	Dev U	S	16.0	20	AMC		Queenston shale	4,619
7			See text	Dev U	S	15.0	14	AMC		Oriskany	3,225
8	1,3xx	40	See text	Dev U	S	17.0	20	AMC			
9			See text	Dev U	S	17.0	20	AMC		Salina shale	5,252
10			See text	Dev U	S	15.0	15	AMC		Queenston shale	7,930
11			See text	Dev U	S	16.5	16	AMC			
12		70	See text	Dev U	S	18.0	20	AMC			
13		40	See text	Dev U	S	13.0	14	AMC			
14			See text	Dev U					10,347		
15		70	See text	Dev U	S	18.0	16	AMC			
16		40	See text	Dev U	S	18.0	16	AMC			
17	1,3xx	40	See text	Dev U	S	18.0	22	AMC		?	5,575
18	1,4xx	40	See text	Dev U	S	18.5	22	AMC		?	7,248
19		40	See text	Dev U	S	19.0	20	AMC			
20											
21	1,030	dry	Oriskany	Dev L	S	9.x	50	AF		Vernon shale	7,148
22											
23	1,020	dry	Oriskany	Dev L	S	9.x	50	AF			
24											
25			See text		S			AMC			
26			See text		S			AMC			
27			See text		S			AMC			
28			See text		S			AMC			
29			See text		S			AMC		?	7,003
30			See text		S			AMC		Salina shale	8,220
31			See text		S			AMC			
32			See text		S			AMC		Salina shale	7,756
33									30,016		

TABLE 2.—*Principal Oil and Gas-producing Sands of Pennsylvania*

Field	County	Sand
Bradford	McKean	Chipmunk
		Second Bradford
		Third Bradford
		Fourth Bradford (Windfall)
		Lewis Run
		Fifth Bradford (Kane of the Bradford)
		K[illegible]
		Sixth Bradford (Haskell)
Kane to Butler	McKean	(as above)
	Warren	Glade
		Clarendon
		Gartland
	Venango	First Venango
		Second Venango
		Third Venango
		Speechley
	Forest	First Venango (Hundred Foot)
		Second Venango
		Third Venango
		Speechley
		Tiona
		Third Bradford
	Elk	Speechley
		Tiona
		Balltown
		Sheffield
		First Bradford
		Second Bradford
		Third Bradford
		First Kane
		Second Kane
		Third Kane
		First Elk
		Second Elk
		Third Elk
	Butler	Hundred Foot
		Butler
		Thirty Foot
		Gordon
		Fifth
		Speechley
Southwest Pennsylvania	Butler	(as above)
	Allegheny	Murraysville
		Gantz
		Fifty Foot
		Thirty Foot
		Gordon
		Fourth
		Fifth
		Bayard
		Elizabeth
	Tioga	Oriskany
	Potter	Oriskany
Miscellaneous Gas	Potter	Third Bradford (Ruhburg)
		First Kane
	Fayette	Gantz
		Fifty Foot
		Gordon
		Fourth
	Jefferson	Fifth Warren
		Second Kane
	Westmoreland	Murraysville
		Hundred Foot
		Fourth
		Fifth
		Bayard
		Elizabeth
		Speechley
		Squaw

The second geographical unit carried in Table 1 is the region known as Kane to Butler. The boundaries are indefinite and the productive acreage lies within the several counties noted in Table 1. Such a variety of conditions prevails in this region and so many different sands are productive (note Table 2) that generalizations may be misleading. Here it is that the influence of local fingering, lensing and pinching out of strata and of change in its properties is exemplified to the greatest extent. Apparently the whole region is one vast oil field with the more prolific areas, those commercially profitable, known as distinct pools. An adequate geologic explanation of these facts is needed greatly. The economic problem of the region is the recognition and profitable operation of the more prolific areas. Sand conditions are so variable that the only method of secondary recovery practicable at present is air or gas repressuring. Its potentialities are just being fully recognized. Natural recovery is too slow and costly to be tolerated throughout most of the region.

The average saturation of the more prolific areas is in the neighborhood of 27 per cent. The sands are too often thin, but are shallow and in many cases two, three or four are productive. It is estimated that the region has an oil content of around 2,000,000,000 bbl., of which only 125,000,000 bbl. are recoverable by present methods and at present price levels.

Much of what has been said of the Kane to Butler field can also be said of the oil-producing region of southwestern Pennsylvania, except that even less is known concerning it. Very few cores from wells in the region have been studied, little authentic information is on record. It is believed that important reserves exist in the region. Oil saturation probably is less, averaging not over 25 per cent. The average depth of wells is greater. Undoubtedly a total oil content of from 2,500,000,000 to 2,800,000,000 bbl. exists in this region. The probable economical recovery cannot be estimated at this time but undoubtedly will be less than in the Kane to Butler region. Secondary methods of recovery have been practiced upon only the most limited scale but are believed to offer interesting potentialities.

Natural Gas

Little can be said about the production of natural gas in Pennsylvania in 1933, with the possible exception of the Tioga and Potter county fields, other than that it is on a stable basis. Rock pressures are known to vary from a few pounds to as high as 1100 lb. but reliable information in detail cannot be procured at this time. In many cases casinghead gas produced under high vacuum is marketed also. The principal events in the Farmington and Hebron fields were the subsidence of intensive development and the increased withdrawals due to better

market facilities. Considerable exploration work has been done and further exploration is contemplated in Tioga and Potter counties as well as contiguous areas. An event of importance to the producers in the Hebron field was the completion late in 1933 of the 20-in. connecting line to the Farmington-Syracuse pipe line. It should be noted that the figures for total gas produced in the Farmington field, Tioga County and the Hebron field, Potter County (Table 1), include 2 billion cubic feet for the former and 450 million cubic feet for the latter, owing to gas wasted in drilling in, gas used by the companies and free gas supplied to lessees. The production for the years of 1932 and 1933, however, are actual pipe-line sales.

The comparative production data for natural gasoline for the past three years are presented in Table 3.

TABLE 3.—*Production of Natural Gasoline in Pennsylvania*

Year	Quantity, Thousands of Gallons
Total to 1930	282,029
1931	14,339
1932	15,047
1933	14,385
Total	325,800

As shown in Table 1, much of the natural gas is rich in gasoline, owing to long years of application of vacuum to casingheads. However, the average gasoline content of total natural gas processed has been decreasing steadily since 1915, because of the increasing volumes of gas treated. This is due to the relative growth of the absorption process at the expense of the compression. Natural gasoline was extracted from nearly fifty billion cubic feet of natural gas in Pennsylvania last year at an average yield of 0.3 gal. per thousand cubic feet.

Application of Scientific Knowledge

It should be emphasized that the important development work accomplished in 1933 in Pennsylvania was not of an exploratory nature but rather an application of scientific knowledge and methods toward the solution of the great economic problem of the oil-producing region; namely, the profitable operation of partially depleted reserves at current prices for crude. This has meant intensive study and appreciation of local conditions for (in many instances) the first time, elimination of marginal and submarginal territory, betterment of the physical condition of wells and equipment, elimination of waste in effort, materials and product, and the increased application of sound methods of secondary recovery to the more prolific leases or portions of leases. It is felt that

the day of the haphazard, take-what-may-come producer is approaching its logical end.

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Oil and Gas Production in Tennessee in 1933

By L. C. Glenn,* Nashville, Tenn.

(New York Meeting, February, 1934)

The account of oil and gas production in Tennessee, and of the geological factors related to such production, as given by the writer[1] a few years ago needs to be supplemented by brief statements as to production and development to bring it up to date. Activity in searching for favorable geological structures or in drilling given areas has never been comparable to the intensive work done in states of large production. It is not possible, therefore, to prepare a statement giving the details that may be readily available in such states, but instead one must be content with more general statements.

In the past 10 or 12 years there has been a moderate amount of drilling for both oil and gas widely scattered over the state. Of much of this there is no available record. Morgan, Clay, Scott and Pickett counties have had more oil-drilling activity than any other counties, and likewise they have had almost all of the oil production. In Scott and Morgan counties production centers about Sunbright and Glenmary, the oil coming from the St. Louis limestone at a depth of 1200 to 1500 ft. Wells usually are small but generally hold up well.

In Clay, Pickett, Fentress, Overton, Macon and Sumner counties there is a large area in which there are many small structural domes, some of which have been drilled. Wells vary from a few barrels to several hundred flush production and last for some years. The oil comes from porous weathered zones, mostly in the Trenton division of the Ordovician, though some comes from lower horizons beneath one or more bentonite beds that serve as horizon markers and are known as the "pencil cave."

Wells recently drilled in the Central Basin and in the Western Highland Rim have been dry or have had only shows of oil. The horizons tested are also usually Ordovician in the Central Basin and usually either Ordovician or Mississippian; occasionally also Devonian on the Highland Rim.

In the Gulf Embayment area of West Tennessee there has been but little activity. A well near Ridgely said to be over 2200 ft. deep is supposed to have entered Upper Cretaceous sands and clays in the lower

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[1] L. C. Glenn: Oil Fields of Kentucky and Tennessee. *Trans.* A.I.M.E. (1921) **65**, 122–139, and Oil Developments and Prospects in Tennessee. Amer. Assn. Petr. Geol. *Bull.* (1921) **5**, 168–172.

hundred feet or so, but its record is more puzzling than illuminating. In the Embayment area surface prospecting is virtually worthless, though some remarkable imagined surface structures have been reported there from time to time. Careful geophysical work there might reveal oil areas similar, in general, to that at Smackover, Ark., for the section of rocks must be closely similar if not identical, down for 2000 or 3000 ft., especially in the general vicinity of Memphis and for some distance north and east of there.

Formerly the crude oil was shipped by tank car, pipe line or river barge and statistics of production were reasonably complete and reliable. For the last few years, however, there has been a marked tendency to install small, local skimming or topping plants in the fields and market locally the gasoline produced. Shipments of crude out of the state have been correspondingly curtailed, and for several years it has been impossible to secure satisfactory figures of production. Producers do not answer requests for such information and no law compels them to do so. Table 1 gives as accurately as is now possible the past production of the state, the last three years being based on very fragmentary data.

TABLE 1.—*Production of Crude Oil in Tennessee* (1866–1933)

		Barrels
1866–1867	Spring Creek field, Overton Co.	20,000
1866–1877	Eagle Creek, Pickett Co.	1,000
1866–1885	Jones Creek, Dickson Co.	500
1892–1906	Spurrior-Riverton, Pickett Co.	58,776
1916	State total	677
1917	State total	12,196
1918	State total	8,374
1919	State total	15,350
1920	State total	14,000
1921	State total	12,000
1922	State total	9,800
1923	State total	8,500
1924	State total	8,500
1925	Scott Co., Morgan Co.	22,535
1926	Clay Co., Scott Co., Morgan Co.	33,725
1927	Clay, Pickett, Scott, Morgan counties	58,564
1928	Clay, Pickett, Scott, Morgan counties	46,983
1929	Clay, Pickett, Scott, Morgan counties	19,776
1930	Clay, Pickett, Scott, Morgan counties	21,080
1931	State total, estimated	15,000
1932	State total, estimated	12,500
1933	State total, estimated	12,500
		412,336

Gas occurs near Sunbright and Glenmary at the same horizons as the oil there. Some wells have two to three million feet open flow with closed pressure of 150 to 200 lb. Plans are being made to pipe the gas to several near-by towns and to Knoxville. Additional drilling is neces-

sary before the extent of the gas field can be determined. How the wells will stand up when put to use can only be determined in the future.

At a number of places, especially on the northern and eastern Highland Rim, from the Kentucky line around east and south to Alabama, gas has been obtained at depths that range from 200 or 300 to 1200 ft. from weathered porous zones that mark unconformities in Ordovician limestones. The open-flow volume is often several million feet. Closed-in pressures are usually low. Such wells are found near Red Boiling Springs, Cookville, Sparta, McMinnville, and Smithland. There is not enough experience with these wells to determine their life or probable yield or to know whether, as widely scattered as they are, they may all be expected to behave in a similar manner.

Petroleum in the Central Texas Area during 1933

By R. B. Kelly* and Paul R. Martin,† Fort Worth, Texas

(New York Meeting, February, 1934)

Drilling in Central Texas during 1933 was confined, for the most part, to the search for new serpentine plugs. Bastrop County led in this particular activity, with 50 completions during the 12 months' period, 12 of which were productive. Only one new field was opened in Central Texas during the year, it being known as "Hilbig" (Bastrop County) and was discovered by the Humble Oil & Refining Co. The finding of commercial production in the serpentine at 2500 ft. led to further search in this and surrounding counties, but without success.

Bexar County actually provided the greatest amount of drilling but the activity was limited to shallow development from 400 to 2000 ft. The Edwards limestone pay, which has been such a factor in past years, received but slight attention during 1933. Unsuccessful exploration was carried on in Lee and Burleson counties. With the exception of Freestone County, the Woodbine sand area was given even less consideration. This county, because of its close proximity to Anderson and Leon counties, saw a very active leasing campaign and several important tests drilled.

In Central Texas, 252 wells were completed in 1933, and of this number 52, or 21 per cent, were productive.

Hilbig Field

The discovery well, Humble Oil & Refining Company's Annie Hassler No. 1, was completed Feb. 16, 1933, for an initial production of 65 bbl. the first hour, through tubing and ½-in. choke. The production was found in serpentine at 2468 ft. and tested 37.2° A.P.I. gravity. Twelve producing wells were drilled during the year and served to indicate that not more than 300 acres would comprise the entire field. Daily production at the end of the year was 775 bbl., although the field potential was 18,240 bbl. daily through 1-in. choke. The field adapts itself to pressure maintenance, and this scientific handling is being undertaken by the Humble Oil & Refining Co. through one injection well. It is the only area in the district where work of this nature is under way.

Proration of Oil

The more stringent application of proration in 1933 did not affect materially the producing fields in Central Texas. This is accounted for

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largely by the "Marginal Well" law of Texas which protects the majority of wells from heavy reductions applied in flush fields of the state. Darst Creek with a potential production of 130,250 bbl. per day and Salt Flat with an estimated 6472-bbl. daily potential, during the latter part of the year were producing 9420 and 4720 bbl. respectively. These fields, together with Hilbig, were the only areas feeling the application of the reduced allowables.

Drilling and Production Practice

As during previous years, the use of rotary tools for drilling continued to predominate, the only exception being the use of spudders for the shallow development in the San Antonio area. Deep drilling to Trinity sands was not undertaken, so the district failed to see the improved rotary machinery and modern deep well practices now being developed in other sections of the state. It is expected, however, that in the near future Central Texas will be explored profitably below the present producing horizons.

Low crude prices during the year caused many operators to seek more economical means of pumping, with the result that many central powers were installed even in fields formerly considered only suitable for standard rigs. Back-cranking was resorted to by some operators not desiring to construct powers.

Few areas in the state produced larger quantities of salt water with the oil than did those fields comprising the Woodbine fault zone of Navarro, Freestone and Limestone counties. Operators in the Powell field, for example, handled an average of 27 bbl. of salt water to recover one barrel of oil. In the Mexia field the average was somewhat less, being 17 bbl. of water per barrel of oil. Despite these high operating costs, most producers were able to come through the year with relatively few abandoned properties.

The use of acid for treatment of dolomitic and limey formations resulted in many substantial increases in oil production. The Edwards limestone fields reacted more favorably to acid treatment than the other producing horizons. By this method production of oil and water was increased in a number of wells in Luling, Salt Flat and Darst Creek fields during the year. It is anticipated that further work of this nature will be attempted during the coming year.

No casinghead gasoline or vacuum plants were constructed during 1933.

Although relatively inactive during 1932 and 1933, because of development in Southwest Texas, particularly Duval County and continued drilling in the proven area of the East Texas field, Central Texas wildcatting and field development has been curtailed. Generally improved conditions in the petroleum industry, with better crude prices now prevalent, will result in much increased activity during 1934.

TABLE 1.—*Oil and Gas Production in Central Texas*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Somerset, *Atascosa, Bexar*	21	11,390	0	11,390	9,257,613	366,275	306,075	855
2	Hilbig, *Bastrop*	1	250	0	250	214,154	0	214,154	784
3	Schimmel-Batts, *Bastrop*	2.5	50	0	50	3,000	800	1,800	5
4	Yost, *Bastrop*	5	97	0	97	775,168	50,370	39,420	108
5	Alta Vista, *Bexar*	18	300	0	300	98,500	3,650	3,285	9
	Alta Vista—Austin Chalk[1,2]								
6	Cooksey, *Bexar*	4	50	0	50	50,405	27,762	16,425	45
7	Eckert, *Bexar*	5.7	640	80	720	415,741	106,355	178,850	490
8	Gas Ridge, *Bexar*	21	60	300	360	52,840	5,120	4,745	13
9	Mission,[1] *Bexar*	22[3]	200	0	200	63,000	0	0	0
10	Yturri-southon, *Bexar*	11.5	500	0	500	514,203	42,577	28,800	80
11	Branyon, *Caldwell*	2.5	20	0	20	63,228	13,740	13,140	36
12	Buchanan, *Caldwell*	4.5	75	0	75	138,583	23,458	20,805	57
13	Dale, *Caldwell*	6	175	0	175	1,094,665	83,521	266,450	730
14	Dunlap, *Caldwell*	2.5	25	0	25	213,265	61,320	20,075	55
15	Larremore, *Caldwell*	5.5	50	0	50	195,965	24,780	23,725	65
16	Luling, *Caldwell, Guadalupe*	12	2,130	0	2,130	57,926,218	2,649,123	2,343,300	6,420
17	Lytton Springs, *Caldwell*	8	1,360	0	1,360	7,619,339	207,901	192,720	528
18	Lytton Springs Townsite, *Caldwell*	5	50	0	50	6,080	730	400	1
19	Salt Flat, *Caldwell*	5.5	1,195	0	1,195	30,286,242	2,931,857	1,861,500	5,100
20	Chilton, *Falls*	11	40	0	40	88,200	6,700	5,475	15
21	Marlin, *Falls*	2	10	0	10	10,000	5,600	4,400	10
22	Wortham, *Freestone, Limestone*	8	715	0	715	22,356,145	56,145	41,400	115
23	Ottine,[6] *Gonzales*	5[6]	10	0	10	12,000	0	0	0
24	Darst Creek, *Guadalupe*	4.5	1,670	0	1,670	28,758,509	5,941,847	3,212,000	8,800
25	Manford, *Guadalupe*	3.5	20	0	20	328,828	31,140	19,710	54
26	Bains Creek, *Limestone*	9	0	60	60	0	0	0	0
27	Cedar Creek,[7] *Limestone*	7[7]	25	0	25	297,945	0	0	0
28	Kosse,[8] *Limestone*	11[8]	10	0	10	33,000	0	0	0
29	Mexia, *Limestone*	13	3,920	0	3,920	92,340,600	1,009,600	840,600	2,303
30	Nigger Creek,[9] *Limestone*	8[9]	170	0	170	2,998,810	0	0	0
31	South Bosque, *McLennan*	31	5,300	0	5,300	74,400	8,400	8,550	24
32	Adams, *Medina*	9	0	2,000	2,000	0	0	0	0
33	Chacon Lake, *Medina*	3	350	225	575	3,500	1,500	1,800	32
	Chacon Lake—Shallow[2]								
34	Ina, *Medina*	10.5	310	0	310	140,350	5,400	5,840	16
35	Taylor Pool, *Medina*	8.5	30	0	30	23,768	2,928	2,920	8
36	Minerva-Rockdale, *Milam*	12	4,000	0	4,000	3,017,639	101,881	93,075	255
37	Angus, Edens, Hodge, *Navarro*	18	900	0	900	1,534,052	14,020	13,505	37
38	Burke, *Navarro*	18	250	0	250	306,460	4,820	4,645	13
39	Chatfield,[10] *Navarro*	29[10]	0	150	150	0	0	0	0
40	Corsicana, *Navarro*	37	2,400	0	2,400	4,662,700	42,110	34,675	95
41	Currie, *Navarro*	11	475	0	475	6,558,500	130,645	58,500	150
42	Mildred or Elm Ridge, *Navarro*	33	2,500	0	2,500	5,778,373	57,370	47,180	132
43	Powell, *Navarro*	10	2,600	0	2,600	108,964,830	979,645	964,830	2,800
44	Rice-oil Ridge, *Navarro*	17	660	0	660	1,115,675	10,840	10,585	29
45	Richland, *Navarro*	9	440	0	440	6,581,600	21,900	11,680	32
46	Witherspoon-McKie, *Navarro*	19	400	0	400	806,195	8,790	8,030	22
47	Woodbine Area Shallow Field, *Navarro*	9	750	0	750	736,580	38,610	32,120	88
48	Chapman, *Williamson*	4	350	0	350	3,528,535	431,739	255,597	680
49	Thrall, *Williamson*	19	475	0	475	2,324,162	22,992	16,790	46
50	Total		47,397	2,815	50,212	269,927,012	15,533,961	11,229,576	

[1] No production now; depleted.
[2] Consolidated with preceding line except as to the few entries on this line.
[3] Discovered 1912. Life 16 years; depleted.
[6] Discovered 1929. Life 6 months; depleted.
[7] Discovered 1927. Life 4 years; depleted.
[8] Discovered 1922. Life 8 days; depleted.
[9] Discovered 1926. Life 5 years; depleted.
[10] Discovered 1905. Life 5 years; depleted.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells						
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Gas Only	At End of 1933: Total Producing
1	813	20	1	0	0	0	0	1,045	2	81	75	823	0	898
2	857	x	65	0	0	0	0	12	12	0	0	12	0	12
3	60	x	2	0	0	0	0	3	0	0	0	3	0	3
4	7,991	x	9	0	0	0	0	12	0	0	0	12	0	12
5	328	14	0.5	0	0	0	0	35	0	0	0	18	0	18
6	1,008	101	3	0	0	0	0	15	0	0	0	15	0	15
7	650	65	6	2,645	447	390	1.5	124	15	3	20	85	6	111
8	881	59	2	8,000	248	202	0.7	120	0	12	18	6	55	79
9	315	13	0	0	0	0	0	32	0	0	0	0	0	0
10	1,028	103	1	0	0	0	0	115	0	3	28	78	0	78
11	3,161	x	18	0	0	0	0	2	0	0	0	2	0	2
12	1,848	x	11	0	0	0	0	6	0	0	0	5	0	5
13	6,255	x	29	0	0	0	0	38	0	0	10	25	0	35
14	8,531	853	14	0	0	0	0	5	1	1	0	4	0	4
15	3,919	112	10	0	0	0	0	12	0	0	0	6	0	6
16	27,195	777	13	0	0	0	0	544	0	29	32	479	0	511
17	5,602	x	3	0	0	0	0	295	0	11	18	184	0	202
18	122	x	1	0	0	0	0	3	0	0	0	1	0	1
19	25,344	1,267	21	0	0	0	0	353	0	23	5	241	0	246
20	2,940	588	8	0	0	0	0	3	0	0	0	2	0	2
21	1,000	50	5	0	0	0	0	2	0	0	0	2	0	2
22	31,267	893	8	0	0	0	0	322	0	3	0	14	0	14
23	1,200	80	0	0	0	0	0	1	0	0	0	0	0	0
24	17,221	906	36	0	0	0	0	261	0	10	15	246	0	261
25	16,441	822	18	0	0	0	0	4	0	0	0	3	0	3
26	0	0	0	x	x	x	0.5	5	0	1	1	0	2	3
27	11,918	1,702	0	0	0	0	0	14	0	0	0	0	0	0
28	3,300	x	0	0	0	0	0	1	0	0	0	0	0	0
29	23,556	471	8	0	0	0	0	550	0	10	3	286	0	289
30	17,640	1,764	0	0	0	0	0	75	0	0	0	0	0	0
31	14	4	0.4	0	0	0	0	123	4	0	28	60	0	88
32	0	0	0	10,761.4	437	386	2.5	45	1	6	0	0	16	16
33	10	x	2	1,900	537.5	273.7	0.7	25	8	0	0	20	5	25
34	453	30	2	0	0	0	0	30	0	1	2	10	0	12
35	792	53	4	0	0	0	0	6	1	2	0	2	0	2
36	754	50	0.5	0	0	0	0	575	0	37	33	451	0	484
37	1,705	95	0.8	0	0	0	0	205	2	18	14	44	0	58
38	1,226	111	1	0	0	0	0	85	0	0	6	13	0	19
39	0	0	0	4,750	0	0	0	15	0	0	0	0	0	0
40	1,943	130	0.4	0	0	0	0	1,280	2	55	26	249	0	275
41	13,807	690	11	0	0	0	0	54	0	8	2	14	0	16
42	2,311	144	0.5	0	0	0	0	1,270	2	50	56	258	0	314
43	41,910	1,048	16	0	0	0	0	821	0	29	12	179	0	191
44	1,690	141	0.6	0	0	0	0	95	0	16	18	50	0	68
45	14,958	748	16	0	0	0	0	107	0	7	0	2	0	2
46	2,015	155	0.6	0	0	0	0	85	0	11	8	34	0	42
47	982	655	2	0	0	0	0	185[13]	2	36	21	49	0	70
48	10,082	x	9	0	0	0	0	110	0	15	15	76	0	91
49	4,893	x	5	0	0	0	0	13	0	4	2	9	0	11
50				28,056.4	1,669.5	1,351.7	5.9	9,138	52	482	468	4,072	84	4,624

[b] Footnotes to column headings and explanation of symbols are on page 175.
[13] Includes 50 Woodbine depleted wells plugged back and casing ripped to produce shallow oil.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1933				Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1933				
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells: Flowing	Number of Wells: Pumping	Number of Wells: Gas-lift	Injection into Reservoir[d]	Initial	Average at End of 1932	Average at End of 1933	Gravity A.P.I. at 60°F. Maximum	Gravity A.P.I. at 60°F. Minimum	Gravity A.P.I. at 60°F. Weighted Average	Sulfur, Per Cent	Base[f]
1	2,100	1,400	0	823	0		x	x	x	39.4	34.0	36.4	1.4	P
2	2,575	2,450	12	0	0	G	1,240		1,150	37.2	37.2	37.2	0.2	P
3	1,900	1,400	0	3	0		x	x	x	34.8	33.8	34.4	0.2	P
4	1,500	1,335	0	12	0		x	x	x	27.7	27.1	27.4	0.3	P
5	250	220	0	18	0		x	x	x	x	x	35.0	0.3	P
	1,150	1,000										21.0	1.3	
6	1,460	1,440	0	15	0		x	x	x	33.5	33.0	33.3	0.4	P
7	670[4]–790[5]	655[4]–620[5]	0	85	0		200	170	160	34.5	33.0	33.7	0.3	P
8	830[4]–280[5]	780[4]–230[5]	0	6	0		220	150	140	23.0	21.0	22.0	0.4	P
9	420	395	0	0	0		x	x	x	28.0	27.5	27.8	0.3	P
10	800	600	0	78	0		x	x	x	32.5	31.4	32.0	0.5	P
11	2,000	1,900	0	2	0		x	x	x	37.5	37.5	37.5	0.8	P
12	2,075	1,750	0	5	0		x	x	x	37.0	35.0	35.5	0.2	P
13	2,250	1,915	0	25	0		x	x	x	38.4	37.8	38.0	0.2	P
14	2,300	2,290	0	4	0		x	x	x	37.0	36.3	36.4	0.6	P
15	1,315	1,285	0	6	0		x	x	x	23.4	23.0	23.0	0.2	P
16	2,200	2,100	0	511	0		x	x	x	27.7	27.0	27.3	0.9	A
17	1,900	1,600	0	184	0		x	x	x	38.6	37.8	38.1	0.4	P
18	1,820	1,535	0	1	0		x	x	x	31.5	31.5	31.5	0.4	P
19	2,740	2,670	0	241	0		x	x	x	36.0	36.0	36.0	0.6	P
20	1,160	1,080	0	2	0		x	x	x	32.0	31.6	31.8	0.8	P
21	1,160	1,000	0	2	0		x	x	x	34.5	33.9	34.2	0.4	P
22	3,050	2,990	0	14	0		x	x	x	38.6	36.2	37.3	0.2	P
23	3,780	3,765	0	0	0		x	x	x	31.5	31.5	31.5	0.2	P
24	2,700	2,650	12	249	0		x	x	x	36.8	36.0	36.5	0.8	P
25	2,320	2,260	0	3	0		x	x	x	37.3	36.7	37.3	0.9	P
26	2,960	2,945	0	0	0		875	355	240					
27	2,940	2,885	0	0	0		x	x	x	37.3	37.3	37.3	0.3	P
28	3,767	x	0	0	0		x	x	x	31.9	31.9	31.9	0.3	P
29	3,085	3,000	0	286	0		x	x	x	36.0	34.2	35.0	0.3	P
30	2,870	2,820	0	0	0		x	x	x	40.0	39.0	40.0	0.3	P
31	475	450	0	60	0		x	x	x	42.0	41.0	41.0	0.2	P
32	1,000	900	0	0	0		400	175	125			Gas Only		
33	810[4]	795[4]	0	7	13		420	290	240	36.0	34.0	35.0	0.1	P
	800[5]	760[5]												
	320[5]–495[4]	240[5]–480[4]								22.0	20.0	21.0		
34	960	940	0	10	0		x	x	x	19.0	19.0	19.0	0.7	A
35	400	290	0	2	0		x	x	x	18.0	18.0	18.0	0.4	P
36	1,700	600	0	451	0		x	x	x	40.0	36.4	38.0	0.2	P
37	1,185	740	0	44	0		x	x	x	36.5	36.1	36.3	0.6	P
38	480	400	0	13	0		x	x	x	20.5	19.8	20.3	0.8	P
39	1,020	880	0	0	0		250							
40	1,260	800	0	249	0		x	x	x	37.1	35.9	36.6	0.3	P
41	2,990	2,930	0	16	0		x	x	x	41.0	40.0	40.2	0.2	P
42	1,250	740	0	258	0		x	x	x	20.2	19.3	19.8	0.6	P
43	3,000	2,925	0	179	0		x	x	x	38.0	36.8	37.2	0.3	P
44	1,000	960	0	50	0		x	x	x	36.4	35.2	35.7	0.4	P
45	3,040	2,975	0	2	0		x	x	x	38.4	38.4	38.4	0.3	P
46	875	825	0	34	0		x	x	x	19.6	19.0	19.3	0.6	P
47	1,650	1,450	0	49	0		x	x	x	34.8	34.1	34.5	0.4	P
48	1,915	1,730	0	76	0		200	150	110	36.7	35.2	35.7	0.2	P
49	1,000	700	0	9	0		x	x	x	37.6	36.4	37.0	0.3	P
			24	4,084	13									

[4] Gas.
[5] Oil.

TABLE 1.—(*Continued*)

Number Line	Character of Gas Approx. Average during 1933: B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.	Reference to Text[k]
1		*x*	Taylor, Navarro	Cre U	SH	22	400	F, T	75	Trinity Sand	5,311	
2	1,300	1.0	Serpentine	Cre U	P	12	*x*	Int'n	5	Serpentine	2,715	O, P
3	1,120	1.5	Serpentine	Cre U	P	13	*x*	Int'n	7	Top Austin Ch	2,001	
4	*x*	1.4	Serpentine	Cre U	P	15–25	*x*	Int'n	[illegible]	Austin Chalk	2,066	
5	1,135	*x*	Navarro Sand	Cre U	S	*x*	23	F	25	Trinity Sand	4,535	
			Austin Chalk		C		90					
6	*x*	0.3	Taylor Sand	Cre U	S	13	10	F	5	Edwards Ls	2,250	
7	1,140	1.8	Navarro	Cre U	S	16	10	F	10	Edwards Ls	1,590	
8	1,120	0.5	Taylor Sand	Cre U	SH, S	15–20	15	A	36	Glenrose Ls	2,250	
9	1,120	1.3	Navarro Sand and Shale	Cre U	S.H	18	25	F	15	Glenrose Ls	3,550	
10	*x*	1.8	Navarro Sand	Cre U	S.	16	10	F	26	Glenrose Ls	3,850	
11	*x*	1.5	Crevice, Top Austin	Cre U	C	*x*	*x*	F	8	Edwards Ls	2,450	
12	*x*	1.6	Serpentine	Cre U	P	12	*x*	Int'n	2	Edwards Ls	2,483	
13	*x*	1.5	Serpentine	Cre U	P	15	*x*	Int'n	6	Edwards Ls	2,661	
14	*x*	1.5	Austin Chalk	Cre U	C	*x*	10	F	9	Edwards Ls	2,420	
15	1,120	1.3	Edwards Ls	Cre L	L	*x*	35	F	6	Glenrose Ls	2,150	
16	955	1.5	Edwards Ls	Cre L	L	5–30	35	F	73	Schist	7,859	C
17	1,040	1.5	Serpentine	Cre U	P	14	*x*	Int'n	42	Edwards Ls	2,292	
18	*x*	*x*	Serpentine	Cre U	P	12	*x*	Int'n	12	Edwards Ls	2,050	
19	*x*	2.5	Edwards Ls	Cre L	L	30	20	F	36	Edwards Ls	2,918	C, P
20	*x*	2.1	Buda or Georgetown	Cre L	Ls	23	5	AF	23	Glenrose Ls	2,025	
21	*x*	*x*	Buda or Georgetown	Cre L	L	20	20	AF	8	Glenrose Ls	1,409	
22	1,080	2.5	Woodbine	Cre U	SH	25	35	F	62	Glenrose Ls	4,825	
23	*x*	*x*	Taylor Sand	Cre U	S	*x*	15	F	3	Edwards Ls	4,281	
24	*x*	2.3	[11]	Cre L	L	26	25	F	19	Edwards Ls	3,200	P, C
25	*x*	1.5	Edwards Limestone	Cre L	L	35	20	F	3	Edwards Ls	2,800	
26	1,040	0.4	Woodbine	Cre U	SH	20	15	F	9	Woodbine	3,208	
27	*x*	*x*	Woodbine	Cre U	SH	25	7	F	9	Woodbine	3,310	
28	*x*	*x*	Unknown	*x*	*x*	*x*	*x*	Crev	22	Glenrose	6,050	
29	1,152	2.5	Woodbine	Cre U	SH	25	50	F	137	Trinity Sand	6,090	W
30	*x*	*x*	Woodbine	Cre U	SH	25	10	F	35	Woodbine	3,509	
31	1,225	2.0	Basal Walnut	Cre L	DL	22	3	AF	100	Basal Trinity	1,800	
32	999	2.3	Escondido Sand	Cre U	S		20	F	8	Edwards Ls	2,289	
33	1,095	0.5	Serpentine	Cre U	P	*x*	*x*	Int'n	12	Edwards Ls	1,725	
			Navarro, Taylor		S	13		D				
34	*x*	*x*	Escondido Sand	Cre U	SH	*x*	15	F	32	Edwards Ls	2,048	
								Crev	14	Escondido S.	1,250	
35	*x*	1.4	Sand	Cre U	SH	15	15	F				
36	*x*	2.5	Upper Navarro	Cre U	S	16	15	F	42	Edwards Ls	5,000	
37	1,040	2.8	Nacatoch, Corsicana	Cre U	Ss	12–18	18	AF, AM	65	Woodbine Sand	3,335	
38	1,040	*x*	Nacatoch Sand	Cre U	Ss	18	11	A	25	Woodbine Sand	3,356	
39	1,110	1.8	Taylor Sand	Cre U	Ss	*x*	13	A	7	Woodbine Sand	3,057	
40	1,040	1.8	Nacatoch, Corsicana	Cre U	Ss	13–19	15	AF, AM	118	Woodbine Sand	3,408	
41	1,040	2.5	Woodbine Sand	Cre U	SH	22	20	F	50	Woodbine Sand	3,300	
42	1,040	1.7	[12]	Cre U	Ss	14–20	16	AF, AM	300	Woodbine	3,570	
43	1,080	2.5	Woodbine	Cre U	SH	25	40	F	67	Glenrose Ls	4,753	W
44	1,040	1.9	Nacatoch Sand	Cre U	Ss	12–17	12	AF, AM	28	Woodbine	3,086	
45	1,060	2.5	Woodbine Formation	Cre U	SH	25	20	F	20	Glenrose	5,415	
46	1,040	1.6	Nacatoch Sand	Cre U	Ss	14–19	13	Af	25	Woodbine	3,480	
47	*x*	*x*	Sands in Taylor-Navarro	Cre U	Ss	14–20	15	F	48	Glenrose	4,753	
48	1,025	0.8	Serpentine	Cre U	P	15–25	*x*	Int'n	43	Edwards Ls	3,236	
49	*x*	0.8	Serpentine	Cre U	P	20–30	*x*	Int'n	23	Trinity	3,290	

[11] Taylor Marl, Austin Chalk cavities and Edwards Limestone.
[12] Nacatoch, Corsicana Sand, Taylor and Navarro.

TABLE 2.—*Summary of Drilling Operations in Central Texas*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934											Completed during 1933										Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes										Productive Wells (For Details See Table 1)	Dry and/or Near-dry Holes									Productive Wells (For Details See Table 1)		
	Total Depths, Ft.											Total Depths, Ft.											
	400–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	8000–9000	Total		400–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000	Total		Within Fields	Exploratory
Atascosa	8	19	14	5	5	0	0	0	0	51	500	5	6	0	0	0	0	0	0	11	0	0	2
Bandera	1	0	0	1	1	0	0	0	0	3	0	1	0	0	0	0	0	0	0	1	0	0	1
Bastrop	11	76	107	25	3	1	0	1	0	224	27	2	4	30	1	0	0	0	1	38	12	3	2
Bell	5	9	1	2	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	1
Bexar	195	118	100	43	8	2	0	0	0	466	953	23	12	2	0	0	0	0	0	37	17	5	4
Blanco	7	2	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	1
Bosque[1]	14	7	2	2	0	0	0	0	0	25	2	0	0	0	0	0	0	0	0	0	0	0	0
Brazos	0	1	4	4	1	0	0	0	0	10	0	0	0	1	2	0	0	0	0	3	0	0	1
Burleson	4	9	5	4	0	0	0	0	0	22	0	0	0	1	0	1	0	0	0	2	0	0	2
Burnett	3	0	1	0	0	0	0	0	0	4	0	1	0	0	0	0	0	0	0	1	0	0	1
Caldwell	28	48	136	43	5	2	1	1	0	264	1255	1	2	14	1	0	0	0	0	18	1	2	1
Comal	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1
Coryell	0	4	1	3	1	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Edwards	3	3	3	4	0	0	0	0	1	14	0	0	0	0	0	0	0	0	0	0	0	0	1
Ellis	5	6	5	4	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	1
Falls	24	64	16	14	1	0	0	0	0	119	5	0	1	0	0	0	0	0	0	1	0	0	2
Fayette	1	0	9	3	2	0	0	0	0	15	0	0	0	0	0	1	0	0	0	1	0	0	1
Freestone	12	31	170	115	10	2	0	0	0	340	75	0	1	0	0	1	2	0	0	4	0	0	1
Gillespie	2	2	0	0	0	0	0	0	0	4	0	0	1	0	0	0	0	0	0	1	0	0	0
Gonzales	10	17	18	9	12	3	0	0	0	69	1	2	0	2	0	0	0	0	0	4	0	0	4
Guadalupe	26	58	185	18	0	0	0	0	0	287	290	4	3	10	1	0	0	0	0	18	0	1	1
Hamilton	0	0	1	14	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	1
Hays	9	2	6	1	0	0	0	0	0	18	0	1	2	1	0	0	0	0	0	4	0	0	1
Hill[1]	33	18	6	3	1	0	0	0	0	61	2	0	0	0	0	0	0	0	0	0	0	0	1
Johnson	1	3	0	2	1	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	2
Kendall	4	6	5	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	3
Kerr	0	3	3	2	4	1	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	3
Kimble	6	4	3	3	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
Kinney	2	2	3	4	1	1	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0
Lampasas	6	7	5	1	1	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	1
Lee	3	8	3	2	0	0	0	0	0	16	0	0	0	0	0	0	0	1	0	1	0	0	0
Limestone	33	40	194	146	6	3	1	0	0	424	927	0	0	0	0	2	0	0	0	2	0	0	3
Llano	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
McLennan	130	95	64	16	4	1	0	0	0	310	123	1	1	0	0	0	0	0	0	2	4	0	0
Mason	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Medina	40	63	26	10	2	0	0	0	0	141	106	1	4	0	0	0	0	0	0	5	10	1	1
Menard	10	7	2	9	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0
Milam	10	70	36	20	4	0	0	0	0	140	575	0	1	5	0	0	0	0	0	6	0	2	2
Navarro	330	266	187	74	5	2	0	0	0	864	4165	0	0	1	0	1	0	0	0	2	8	0	1
Real	1	2	0	2	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Robertson	3	3	2	8	2	1	0	0	0	19	0	4	0	0	0	0	1	0	0	5	0	0	0
Travis	15	26	5	2	0	0	0	0	0	48	0	4	3	0	0	0	0	0	0	7	0	0	5
Uvalde	4	10	6	4	2	0	0	0	0	26	0	4	2	0	0	0	0	0	0	6	0	0	2
Williamson	15	40	69	5	0	0	0	0	0	129	121	3	13	2	1	0	0	0	0	19	0	4	3
Wilson[1]	3	12	13	9	4	1	0	0	0	42	2	0	1	0	0	0	0	0	0	1	0	0	2
Total	1019	1162	1416	636	86	20	2	2	1	4344	9138	58	57	69	6	6	3	1	1	201	52	18	59

[1] No production now; so small and short-lived, not recorded as field.

Development and Production, East Texas District

By A. R. Denison,* Fort Worth, Texas

(New York Meeting, February, 1934)

The area discussed in this report comprises a group of 38 counties lying in the northeast corner of Texas. It covers all, and extends beyond, the borders of what is commonly described as the East Texas Basin. It includes two major oil fields, Van and East Texas; two major gas fields, Bethany and Waskom; and a number of fields, both oil and gas, of lesser importance. All commercial oil production comes from beds of Upper Cretaceous age and almost exclusively from the basal member, the Woodbine sand. Gas is produced from both Upper and Lower Cretaceous beds with the newer production from the older beds.

Development in Fields

East Texas Field

This field in 1933 continued as in 1932, although to a much less extent, to dominate the drilling and production situation throughout the oil business. The 2466 producers completed in this field during the year are 28 per cent of such wells completed in the United States. The 2556 completions reported in the five counties within which the East Texas field lies are 21 per cent of all such wells reported in the United States. It follows that with such a command of the development situation, every other factor with regard to this field has an important bearing on the entire oil business. As a consequence, the important developments in the East Texas field are the important developments of the year.

Very little new productive territory was added to the already known limits of this enormous field. On the other hand, drilling has shown that with a few very minor exceptions this field is a continuous productive area, with a regular outline and no "dry spots" other than that of a single well surrounded by producing wells.

Drilling was confined to the already proven limits of the field. This consisted essentially of more adequate coverage of leases by wells, the meeting of required offsets and the drilling of a large number of small tracts which developed from subdivision of larger leases due to court action and other causes. The allowable throughout the year was, with minor variable factors, on a per-well basis. With the steady decline in per-well allowable after May, every operator was faced with declining

* Amerada Petroleum Corporation.

yield and turned to additional drilling in an effort to maintain production. Every pretext, legal or otherwise, was called upon by owners of small tracts to enable them to get more wells drilled. This, of course, led to forced offsets on leases otherwise adequately drilled. The number of new locations and completions per week reached a low point in the second week in April, when 18 locations and 18 completions were reported. Development remained at about this rate until June, when a new drilling campaign was instituted. The number of operations rose rapidly and during September, October and November, were nearly stationary at an average of 75 new locations and about an equal number of completions per week. At the close of the year new operations were decreasing slightly but gave evidence of continuing into 1934 at a high level. On Dec. 31 there were 11,875 completed wells on 116,125 acres or an average of one well to 9.7 acres.

Early in the year the Texas Railroad Commission revised the spacing rule in so far as it called specifically for only one well on 20 acres. The distance from property lines and between wells on offset tracts remained unchanged. This brought the regulations more in harmony, as foot measurements had called for 10-acre spacing since the first order was issued. "Exceptions" to the footage rule were freely granted from the early history of the field. The exact number is not known but it is estimated that from one-half to two-thirds of all wells in this field are closer than the standard distance of 330 ft. to the property line and 660 ft. between wells on the same or offset leases.

Drilling costs continued to drop during the year, the average contract price being $1.45 per foot or an average of $5300 per well. This was in part offset by higher cost of labor and equipment, but a substantial saving still remained over the average completion of 1932, which is estimated at $15,000.

The excessively high withdrawal during May and June caused a rapid decline in the average bottom-hole pressures, so that on July 1 it had reached 1220 lb. It was freely predicted that, if such a rate of decline continued for the remainder of the year, two-thirds of the wells in the field would be pumping by January, 1934. This situation, coupled with the low price of materials, led many companies to commence installation of pumping equipment. This movement was further accelerated by the features of the N.R.A. Oil Code, which required higher labor costs for installation and pointed toward higher costs for materials. It is estimated that at least fifteen million dollars worth of pumping equipment was bought and largely installed during the current year. Production was gradually curtailed after June, and after the daily withdrawal had come below 600,000 bbl. per day, the average bottom-hole pressure not only ceased to decline but actually increased to 1260 lb. in December with evidence that such increase would continue at least a short time

into 1934. This largely removed the fear that the field would reach a pumping stage at an early date and placed it far in the future. Wide diversity of opinion is now prevalent as to the flowing life of the field.

On Jan. 16, 1933, a check showed 155 wells making water, 18 temporarily dead and 216 pumping wells. The number of all three classes of wells increased notably during the "million a day" production of May so that on June 1 there were 285 wells making water, 165 dead and 333 pumping. With the reduction in withdrawals and adjustment and increases of bottom-hole pressure, many dead wells again resumed flowing. This was true in part of some wells making water but the effect of the heavy withdrawals overcame the recuperative factors and in December there were 654 wells making water, of which 150 were on the east side of the field and making fresh or brackish water due probably to faulty casing. The number of pumping wells at the close of the year had increased to 556 with 50 additional wells on gas-lift. Twenty dead wells were reported, which probably represented the number in process of putting on the pump.

Van Field

Drilling in this field continued during 1933, but at a much reduced rate. At the close of the year the field had an average of 11 acres for each producing well, which is less density than in the East Texas field. Without doubt, it will be necessary to drill many additional wells to obtain complete recovery from the great thickness of productive sand present in this field. The producing limits of the field were not extended in the Woodbine sand, hence all drilling was confined to offsets or inside locations on proven leases.

In April commercial production was established in a shallower sand than the regular productive horizon of the field. This was not strictly a new discovery although it extended the productive area of the field to the north. Wells that had been drilled for Woodbine production, which were low and dry, had good shallow showings. Several wells were completed good for five to more than 40 bbl. per day at depths ranging from 1200 to 1300 ft. in a sandy zone of Nacatoch (Upper Cretaceous) age. The main producing area of the field has not yet been explored in this horizon, but from indications in the Woodbine wells, it is quite possible that shallow oil may be found over the whole field. The prospective horizons deeper than the Woodbine which showed promise in flank wells have not been further prospected.

Other Areas

Other productive areas in East Texas were extremely quiet, with no new wells at Boggy Creek or Bethany and only one gas well completed at Waskom. Three producing wells at Boggy Creek were abandoned.

Exploratory Drilling

Exploratory drilling during the year resulted in finding three new productive areas and the elimination of one area that looked promising.

Long Lake Field.—The Long Lake area is in the southwest corner of Anderson County at a point where the Trinity River follows a broad meandering course. This area attracted attention because of surface geological evidence, drainage, and showings of gas in shallow wells. The Tide Water and Seaboard oil companies jointly, after exploratory work with the seismograph, located their No. 1 Long Lake Plantation. This operation started in August and after testing gas in sand reached at 5148 ft. was drilled to a depth of 5469 ft. in water sand and plugged back to 5290 ft. It was completed Nov. 2 in a sand and shale section from 5240 to 5290 ft. for an estimated 30 million cubic feet of gas and 1200 bbl. of oil per day plus salt water in quantities ranging up to 35 per cent of total fluid. Shortly thereafter the well was pinched in on a small choke and has produced only lease requirements of gas with an estimated 100 bbl. of oil per day. Although a pipe line connection has been made, all production had gone to lease storage up to Jan. 1, 1934. A second well 1866 ft. west of the discovery was started early in November and completed Jan. 11, 1934, for an estimated 25 million cubic feet of wet gas. A third well ¾ mile southeast of the discovery well was drilling at the close of the year. The structure is reported to cover more than 10,000 acres and in all probability 4000 or 5000 acres may become productive of gas and oil. The thin sand bodies producing in the first two wells and the preponderance of gas make the future oil production from this field uncertain. At present a large gas reserve is demonstrated, but the oil possibilities are indefinite.

Leon County.—Drilling on a unitized block operated by Shell Petroleum Corporation in north central Leon County began in August, 1932. The first well, No. 1 Phillips, was completed as a dry hole in March, 1933, after having good showings of oil but testing salt water in sands of Woodbine age. On the strength of showings in this well and after extensive seismograph work, a second test was started about two miles south of the dry hole. This well, No. 1 Beggs, started in June, 1933, proved to be much higher structurally than No. 1 Phillips. It tested gas only in the upper part of the Woodbine formation and was drilled entirely through this formation, finding the base at 6116 ft. It was plugged back from its total depth of 6140 ft. and completed in a sand and shale series from 5808 to 5852 ft. making an estimated 30 million cubic feet of gas per day. Excellent structural conditions, demonstrated by the two wells finished on this prospect, are reported to cover more than 15,000 acres. How much area may prove productive of gas and whether commercial oil will be found are questions that cannot be answered without further develop-

ment. The sand bodies in the Woodbine formation are thin, varying from 10 to 15 ft. and, as at Long Lake, appear to carry a preponderance of gas. At the close of the year two additional exploratory wells were being drilled.

DeBerry Area.—Renewed interest in prospecting in the central part of Panola County resulted in the discovery of small production from the Blossom sand near DeBerry. At the close of the year three producers had been completed, good for from 15 to 40 bbl. per day. The area has not had a pipe line connection and only a few hundred barrels have been taken out by trucks and tank cars. The area does not have evidence of becoming a large or prolific field.

Jamestown Area.—Early in 1933 a series of wells was started several miles north of the East Texas field, near Jamestown, in Upshur County, where a well had been completed for a small amount of oil in the Woodbine sand in 1932. The discovery well soon went to water and the tests drilled near were all dry holes. This ended the last of the many areas surrounding the field, where high hopes were held by some that a new "shore line" pool would be found.

"Wildcat" Counties.—Exploratory drilling continued active during the year in this district, with 31 of the 38 counties having one or more completed wells during the year. Particular interest was directed to Hopkins County, where a revival of interest in fault-line structures, originally prospected in 1924–26, accounted for eight completions. Henderson County also was active, with nine completions, largely in the central part of the county near the towns of Athens, Murchison and LaRue.

Production

East Texas

Production from the East Texas field during 1933, reported and estimated, totaled 211,586,118 bbl. from 11,863 wells. This sets an all-time world record for withdrawals from a single pool. Recovery to Jan. 1, 1934, reported and estimated, is 467,448,294 bbl., of which more than 60,000,000 is estimated. These figures indicate that 39,380 bbl. of oil have been recovered for each well completed to the end of the year. Of this amount 17,817 bbl. were produced during 1933, or a daily per-well average of 48.8 bbl. This figure seems high in view of the fact that the field has never been allowed to flow at more than a small percentage of its capacity to produce. The gross production to date includes many millions of barrels, which were produced in excess of and beyond the allowable fixed for the field, which increases the average per-well recovery.

The estimated average daily production for the field rose, with a slight interruption in April, from 398,000 bbl. in January to a peak of more than

one million per day in May, then gradually decreased to 433,000 bbl. in December, falling under one-half million barrels for the last three months of the year.

Production for the year was started on Jan. 1, after a 14-day shutdown in December, 1932, for the purpose of taking bottom-hole pressures. Results of these tests were not complete on Jan. 1 and the field was given a flat allowable of 28 bbl. per well until Jan. 10, when an allowable based on 26 bbl. per day plus a factor of bottom-hole pressure above 1000 lb. was inaugurated. This remained in force for 59 days, until March 9, when the Railroad Commission Order on which the allowable was based was held invalid. A new order was issued giving a flat per-well allowable of 36 bbl. until March 20, when a new order was issued based on average sand thickness, bottom-hole pressure and per-well allowable. This method of computing allowable proved as unpopular with the operators as the previous one and the field was shut in April 6, remaining closed until April 23. Taking their cue from the Federal Court decision, which indicated that "capacity to produce" must be an important element in a proration order, the Railroad Commission divided the wells of the field into 273 groups and ordered a 2-hr. open-flow potential test taken on one selected well in each group. The average of the 2-hr. flow was taken as the hourly potential of all wells in each group. The result of these tests was to reestablish the tremendous potential productive capacity of the field. The highest hourly gage was 1048 bbl. while the lowest was 72 bbl. The average for the 273 wells tested was 537 bbl., or 12,888 bbl. per day. At the time of these tests there were 9913 wells in the field, which gives the fantastic figure of 127,758,744 bbl. for the 24-hr. potential. This figure perhaps is no more unreal than similar potential figures on other large pools, as, for example, Yates.

The new order written by the Railroad Commission as a result of these tests set 15 per cent of the average hourly potential as the daily allowable of each well in the field. This totaled 798,888 bbl. daily and went into effect April 24. Using the same percentage, the allowable was revised, owing to added wells, on May 17 to 826,825 bbl. As indicated above, the reported and estimated production at this time ran far ahead of the allowable and was only confined to something over a million barrels per day by the physical inability of all modes of transportation to move a greater quantity of oil. A second potential test was taken in June but without a shutdown of the field. On this test 167 of the same wells used on the April test were used and these showed an average decline of 8.7 per cent, which probably was entirely due to the difference in field conditions when the tests were made. Allowable orders for the field, based on potential flow alone, were subjected to Federal court tests and held valid, hence they were continued throughout the remainder of the year with the percentage factor being gradually reduced, until on

Dec. 31 it was 5 per cent of the hourly potential of 7,535,780 bbl., making a daily allowable of 376,789 bbl., or an average of 31.7 bbl. per well daily. The severity of restriction under this latest order can best be realized by pointing out that a well capable of producing less than 400 bbl. per hour would have an allowable of less than 20 bbl. This would, however, restrict it to less than the marginal well allowable established by statute for any well having the average depth of East Texas wells, hence it is automatically classed as a marginal well and allowed to produce 20 barrels.

The posted price of East Texas oil fluctuated widely during the year. Starting with 75¢ in January, it dropped rapidly to 10¢ late in April, rose to 75¢ early in July, receded to 50¢ on Aug. 1, again rose to 75¢ on Aug. 25, only to drop the next day to 60¢, from which point it was raised successively to 90¢ Sept. 8 and $1 Sept. 30, remaining at this figure to the end of the year. The posted price was influenced by several factors, most important of which was the amount of oil estimated withdrawn, the low prices of 10¢ and 25¢ being coincident with the "million a day" production rate during late April and early May. During a large part of the time of low prices, postings by various companies were not uniform. Pipe lines being taxed to capacity, several companies elected to purchase only part of the allowed production of wells to which they were connected, running the remainder to storage. Many operators, likewise, refused to produce their full allowable during the extremely low prices. Throughout the year there has been excess oil produced in the field designated as illegal or "hot" oil. This has always brought a price 10 to 50 per cent under the posting of major companies. During the time of high production large quantities of oil were sold for 5¢ per barrel and sales were reported even as low as 3¢. The high withdrawals of oil from East Texas and resultant low prices forced down the entire Mid-Continent oil market to 25¢ in May and had a depressing effect on all oil prices throughout the United States. Improved demand and reduced withdrawals from East Texas combined to allow the entire market to rise in September following fluctuations in June, July and August.

Enforcement of proration orders by the Texas Railroad Commission was not completely effective at any time during the year. During the early months, orders were successfully attacked in federal and state courts. The state enforcement laws were inadequate but were partly remedied by legislative acts during the year. Since the state can regulate commerce only within its borders, a large amount of excess production escaped state action by being classed as interstate. This oil was largely shipped by tank cars. In July the President issued an order banning excess oil from interstate shipment and the amount of oil moved by tank cars dropped from more than 125,000 bbl. per day to less than 5000 per day. Federal enforcement authorities were placed in the field in July and remained throughout the year. The state authorities, aided by

TABLE 1.—*Oil and Gas Production in East Texas District*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Nacogdoches, *Nacogdoches*	63[1]	130	0	0	130	2,500±	0	0	0
2	Caddo, *Marion*	29	980	0	0	980	7,463,030	50,021	42,602	107
3	Shelbyville, *Shelby*	15½	50±	0	0	50±	55,901	0	0	0
4	Bethany, *Panola*	15	0	0	21,000	21,000	0	0	0	0
5	Waskom, *Harrison*	9	0	0	7,500	7,500	0	0	0	0
6	Boggy Creek, *Anderson, Cherokee*	6¾		200		200	3,886,273	378,034	290,664	577
7	Van, *Van Zandt*	4½	4,330		0	4,330	58,126,438	17,321,231	17,225,296	37,318
8	East Texas, *Rusk, Gregg, Upshur, Smith, Cherokee*	3⅓	112,125		4,000	116,125	467,448,294±	156,109,346±	211,586,118±	435,918±
9	DeBerry, *Panola*	½	30±	0	0	30±	1,000±	0	1,000±	15±
10	Long Lake, *Anderson*	⅙		40±		40±	5,478±	0	5,478±	100±
	Total		117,645	240	32,500	150,385	536,988,914	173,858,632	229,151,158	474,035

[a] Footnotes to column headings and explanation of symbols are on page 175.
[1] This age applies to the first published date of exploitation.

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells							
									During 1933		At End of 1933				
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Completed to End of 1933	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[c]	Producing Gas Only	Total Producing
1	20	x	0	0	0	0	0	45±	0	0	0	[2]	0	0	0
2	7,615	507±	3	0	0	0	0	78	0	y	0	34	0	0	34
3	1,114±	112±	0	0	0	0	0	5	0	0	0	[3]	0	0	0
4	0	0	0	90,655	11,040	7,930	25	333	y	y	y	0	0	161	161
5	0	0	0	39,020	2,131	1,736	5	208	1	y	0	0	0	83	83
6	19,431	571	27	6,487	973	402	1.8	39	0	3	0	0	21	0	21
7	13,424	50	97	14,964	4,910	5,269	16	397	28	0	7	385	0	4	392
8	4,169±	148±	38±	13,700±	5,268±	7,805±	28.2±	11,875	2,466	0	0	11,863	0	12	11,875
9				0	0	0	0	3	3	0	0	3	0	0	3
10	137	9	100±	x	0	x	x	2	2	0	1	0	1	0	1
				164,826	24,322	23,142	76	12,985	2,500	3	8	12,285	22	260	12,570

[2] All wells abandoned prior to 1900? [3] All wells abandoned prior to 1923.

NOTES WITH REGARD TO TABLE No. 1

There appears to be very little information about any features connected with the development of the old shallow oil field in Nacogdoches County. Perhaps the most extensive reference on this field is in the Second Annual Report of the Geological Survey of Texas (1890). Other references are in *Bulletin* 1, University of Texas Mineral Survey, 1900 and in U. S. Geological Survey *Bulletins* 184, 260 and 282.

Figures under Waskom and Bethany fields for producing horizons are for total depth of deepest producing wells and top of shallowest producing zone. Six or more horizons are known to produce gas in these fields, but the amount from each horizon cannot be calculated from the data available to the author. Gas from all horizons above 3300 ft. has a normal gasoline content. The deeper Glen Rose pay is extremely rich in gasoline.

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1933				Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1933				
	Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells				Initial	Average at End of		Gravity A.I.P. at 60° F.			Sulfur, Per Cent	Base[f]
			Flowing	Pumping	Gas-lift	Misc.		1932	1933	Maximum	Minimum	Weighted Average		
1	100	80	0	0	0	0	x					23	x	A
2	2,366±	2,300±	0	34	0	0	x			x	x	40±	y	P
3	2,700	2,600	0	0	0	0	x					34	y	M
4	4,700±	1,000±	0	0	0	0	y	y	y					
5	4,650±	1,000±	0	0	0	0	y	y	y					
6	3,666	3,632	0	21	0	0	650			40	38	38.5	0.24	P
7	3,000	2,500	318	74	0	0	1,250±	1,180±	1,165±	36	33	35	0.8	P
8	3,665	3,632	11,249	556	50	20±	1,600±	1,377±	1,264±	41.6	38	39	0.25	M
9	2,087	1,990	0	0	0	3	x		x	y	y	y	y	P?
10	5,275	5,178	1	0	0	0	2,150		2,150	42		42	0.07	P
			11,568	685	50	23								

Line Number	Character of Gas Approx. Average during 1933		Producing Rock							Deepest Zone Tested, to End of 1933		
	B.t.u. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average in Feet	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Name	Depth of Hole, Ft.	Reference to Text[k]
1			Cook Mt.	Eoc	SH	Por	x	ML	90±	L. Cretaceous	5,485	R, O
2			Tokio	Cre U	S	20±	15±	A	y	y	y	O
3			Blossom	Cre U	S	Por	10y	ML	14	Fredericksburg	3,805	
4	1,000±	y	Nacatoch, Blossom, Glen Rose, etc.	Cre U Cre L	S, SH, L	Por	y	A	39	Glen Rose	5,860	O
5	1,000±	y	Nacatoch, Blossom, Glen Rose, etc.	Cre U Cre L	S, SH, L	Por	y	A	16	Glen Rose	4,980	O
6	1,500	4	Woodbine	Cre U	S, Ss	25±	34±	Ds	43	Woodbine	4,648	O
7	1,100	2.5	Woodbine	Cre U	S, SH	25	268	AF	46	Trinity	7,501	U, O
8	1,550	2.3	Woodbine	Cre U	S, SH	25±	[4]28±	MU	76	Woodbine	3,894	P, O
9			Blossom	Cre U	SH	Por	y	ML	1	Blossom	2,125	O
10	y	y	Woodbine	Cre U	S	26	15	A	1	Woodbine	5,590	O
									326			

[4] Concerning this very vital factor there is wide difference of opinion among major companies. The estimates vary from 18 to 45 feet.

Gas-production figures for Boggy Creek are for both dry gas and casinghead gas. Both kinds of gas are processed through extraction plants and sold for commercial purposes.

The gross production figure for gas in the Van pool is solely casinghead gas. No gas for commercial purposes is extracted from the dry gas wells in this field.

Gross production figures for gas in the East Texas field are estimated from the capacity of casinghead plants alone. Dry gas has been produced commercially from one well in the gas area in the southern part of the field, but the figures of this recovery are not available. Extensive use has been made of some dry gas wells for drilling and lease requirements by companies owning these wells on other leasehold in the field. No record is available of the amount withdrawn for these purposes.

TABLE 2.—*Summary of Drilling Operations in East Texas District*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934										Completed during 1933									Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes									Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes								Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.								Total		Total Depths, Ft.							Total		Within Fields	Exploratory
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000			0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000				
Anderson	14	22	14	31	16	8			95	34		1	1					2	1		3
Angelina	25	27	8	6	1				67			6						6			2
Bowie		4	22	18	1				45				1	3				4			
Camp		1		3	3				7												
Cass	3	11	20	24	4				62				2		1			3			2
Cherokee		8	9	32	21				70	23				2	2	1		5	1		1
Collin	1	6	2	1					10												
Delta	2	2	3	8					15					1				1			
Fannin	3	3	6	3					15				1					1			
Franklin		5	2	10					17					2				2			
Grayson	27	33	16	5	1	1			83	7	3	1	1			1		6			
Gregg	1	3	7	50	4				65	5,823			2	12				14	1,248	92	
Harrison	6	27	18	6	2				59	208			2	2				4	1		2
Henderson	5	10	5	22	25	1			68						9			9			
Hopkins	4	5	4	22	4				39			1	1	5	1			8			
Houston	1	6	10	4	3	1			25		1	1		1	1			4			2
Hunt		9	7	21	2				39			2			1			3			2
Kaufman	3	4	15	29					51		1			1				2			1
Lamar	4	4	7	2	1				18				1					1			
Leon		4	3	4	1	2	2		16	1							2	2	1		4
Madison	3	3	2						8		2							2			2
Marion		4	45	15	1				66	34			1	1	1			3			2
Morris		1	4	4	1				10					1				1			2
Nacogdoches	2	7	7	14	9	1			[1]40												1
Panola		2	28	13					43	[2]347			5	1				6	3	7	8
Rains		2	2	5	5				14												
Red River	1	16	15	4	1				37				1	2				3			2
Rockwall				1					1												
Rusk	2	8	12	55	7				84	4,620		2	1	14	1			18	955	111	3
Sabine	1	5	6	4	2				18		1							1			1
San Augustine	17	2	4	1	1				25												1
Shelby	2	7	26	31	5	1	1		73	6			3	3	1			7			2
Smith	7	4	13	18	19	2			63	629				1	2	1		4	114	8	2
Titus	3	1	5	9	3			1	22					2				2			
Trinity	2	4	2	2	1				11			1	1	1				3			1
Upshur	1	4	4	46	8		1		64	786		1	1	8				10	157	11	3
Van Zandt	2	13	20	50	10	2	1	1	99	397		5	2	4			1	12	28	5	5
Wood	4	9	5	9	9	2			38					3	2			5			1
Total	146	286	378	582	171	21	5	2	1,582	12,915	8	21	27	70	22	3	3	154	2,509	234	55

[1] Does not include shallow wells in old Nacogdoches field.
[2] Includes 11 oil wells in the Bethany field which are now aband, ed; also 3 oil wells completed in 1933 at DeBerry.

better enforcement laws and by successful defense of proration orders in the federal courts were making progress in bringing the withdrawals somewhere near the allowable figures. The daily estimated withdrawals in December were within 30,000 bbl. of the allowable as compared with a difference of 200,000 in June.

Owing to the great size and large number of wells in the field, it will always be impossible adequately to police the field to prevent overproduc-

tion. Because of this feature considerable effort has been made to prevent excess oil from getting into commercial channels. It is relatively simple to check allowable production against pipe line movement, hence very little excess oil leaves the field in this way. At the close of the year there were 56 refineries, large and small, within the field, which operate exclusively on crude from the field. They sell their product chiefly to tank wagons. It is believed that a large part of the excess oil in the field is handled by these refineries, and concentrated efforts have been made both by federal and state authorities to check the throughput of these plants. Fourteen of these small refineries hold injunctions against examination or checking by the constituted authorities. These refineries are served either by small gathering pipe line systems, owned wholly or in part by them, or by oil trucks direct from the leases. At the close of the year 10 of these small gathering lines were not reporting their movement of oil, having injunctions against such examination. A very useful weapon in controlling these elements has been the ability of the State Attorney General to throw the corporations in receivership where it could be shown that proper gasoline or gross production taxes had not been paid. Movement of oil by trucks largely by night has successfully defied regulation.

Van Pool

This field, being practically a unit operation, produced throughout the year at exactly its allowable as set by the Railroad Commission. Its gross production to date puts it in the ranks of the outstanding major oil pools, but its position is somewhat dimmed by the proximity of the world's largest oil pool. Per-acre recovery to date has been high, but the unusual thickness of pay sand clearly indicates that many thousands of barrels will be added to this figure before depletion.

Miscellaneous

Oil and gas production at Boggy Creek continued the normal decline, with all wells reaching the pumping stage. Gas production at both Bethany and Waskom showed declines over 1932, with little or no additional drilling to obtain drainage or reserves. Oil production in the part of the Caddo field of Louisiana that extends into Marion County is now in the stripper stage and rapidly approaching exhaustion.

Summary and Outlook for 1934

Drilling should remain active throughout 1934 in the East Texas field. If the rate of completions shown during the first weeks continues through the year more wells will be drilled than in 1933. It is estimated that 3000 to 4000 wells will be required to bring the well density on the large tracts to that on the small tracts. A total of 15,000 oil wells may be drilled

eventually in this huge field. Drilling in the new areas of Long Lake and Leon County will be dependent on finding oil production in quantity. Exploratory drilling is expected to at least equal that of 1933 and may exceed this figure if general oil conditions are good. Production from the East Texas pool should not reach the 1933 figure unless much improved demand calls for more oil throughout Texas. Enforcement of proration orders will probably be improved, which should benefit the entire oil industry. Van is expected to continue its steady production and may even exceed the 1933 figure if demand improves.

Acknowledgments

The data used in this report are obtained from many sources, including federal and state statistics, association and Institute publications and trade journals. Accurate production statistics, both for gas and for oil, are very difficult to obtain because of the unwillingness of operators to reveal production and because of the large movement of "hot" or illegal oil produced either surreptitiously or in defiance of the allowable set by the Texas Railroad Commission. This applies particularly to the East Texas field. Thanks are due for information and assistance in compilation to the following: L. T. Barrow, Humble Oil & Refining Co.; A. E. Oldham and C. R. McKnight, Arkansas Natural Gas Co.; Roy T. Hazzard, Gulf Refining Co.; and J. W. Kisling and J. P. Thompson of the Amerada Petroleum Corporation.

Developments on the Gulf Coast of Texas during 1933

By L. P. Teas,* Houston, Texas

(New York Meeting, February, 1934)

In spite of the influx of operators into the Gulf Coast anxious to retrieve their depleted production in other fields, and in spite of very active application of the most scientific geophysical methods to locate new producing areas, the results have been very discouraging and the year has failed to produce more than the average results for a Gulf Coast year.

During the year seven new oil fields, some of which are still of very little importance, and one new gas area have been discovered. These fields are Tom Ball, Greta, Cleveland, Raisin and Garwood in Colorado County; Louise and Premont in Jim Wells County, and the new producing gas area near Ace in southern Polk County. During the year salt has been found for the first time at Carlos and Esperson. New producing areas have been developed on East Stratton Ridge, Hockley, Hull, Port Neches, near Pettus in Bee County, and on the O'Connor Ranch in Victoria County.

The total production for the Gulf Coast for the year was 62,837,435 bbl., an increase of 18,589,000 bbl. over 1932. During the year, 1307 wells have been drilled of which 207 were wildcats, compared with 653 wells and 141 wildcats the previous year. The total daily production at the end of the year was 165,201 bbl. At present there are 3100 oil wells producing. The average production per well is 55.5 bbl. per day. The price of crude fluctuated considerably during the year, beginning at 80¢ per barrel and closing the year at $1.04 per barrel. Completion data for 1933 are as follows:

	Oil Wells	Gas	Dry	Total
Producing fields	919	28	153	1100
Wildcat	7	2	198	207
Total	926	30	351	1307

New Oil Fields

Greta.—Perhaps the most outstanding discovery of 1933 was Greta, in Refugio County, 9 miles northeast of Refugio. Wingo Smith et al. in

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their No. 1 O'Brien encountered a sand 5 to 25 ft. below the top of the Heterostegina zone of the Middle Oligocene from 4396 to 4405 ft., which produced 586 bbl. of 21.5° Bé. oil on a ¼-in. choke. During the last six months of the year development was very active, 86 wells were completed and the limits of the field extended until it now embraces over 5000 acres. The field has not yet been fully defined. In the course of the year the Nesral Oil Co. No. 2 Wilson Heard found a second producing sand, in the Frio, from 5911 to 5920 ft., which produced 400 bbl. on a ¼-in. choke. The gravity of this oil was 38.2° Bé. Toward the end of the year a third sand was encountered in United Production Company's No. 5 Lambert, on the south edges of the field between 3490 and 3506 ft. This sand is in the lower part of the Miocene and produced initially 341 bbl. oil when blown with gas through tubing.

The structure at Greta consists of a broad, slightly arched dome, with local peaks and having at least 100 ft. of productive closure and possibly as much as 200 ft. of total closure. It is probable that some small faults exist. The higher parts of the field contain larger amounts of gas than desirable and in some wells it is necessary to case or blank off the gas. Several blow-outs have occurred in the field from shallower sands. The most troublesome gas sand occurs around 2100 feet.

Tom Ball.—After a very active leasing campaign during the early part of 1933, the Tom Ball field, in northwestern Harris County and in the extreme southwestern part of Montgomery County, about 30 miles northwest of Houston, was brought in by Magnolia-Humble, in No. 1 Jacob Kobs. The well produced initially 69 bbl. of pipe line oil (41° Bé. gravity) per hour through a ½-in. choke from a sand between 5549 and 5569 ft. This sand is of Claiborne age, lying from 175 to 235 ft. below the top of the Cockfield and is equivalent to the main Conroe sand. Development of the field has been slow and orderly, principally because it was soon found that the oil-producing interval on the structure was not over 25 ft. thick and that a very much thicker gas cap lay above the oil. The sand section is not continuous but consists of four or five sands, from 5 to 50 ft. thick, separated by bodies of shale from 18 to 45 ft. thick. Unless one or the other of these sands is found within the thin oil-producing interval a gas well or a dry hole will result even though the well may be located well up on the structure.

The structure is a broad dome, having an uplift above normal of at least 800 ft. and indicating an area productive of either oil or gas of 10,000 acres. The dome is cut by several faults having displacements ranging from 65 to over 200 ft., which add to the difficulty of obtaining good oil wells, although these faults have probably, by placing different sands in juxtaposition, produced general equilibrium of the oil, gas and water throughout the field and thus given rise to a fairly constant gas-oil level and oil-water level.

Cleveland.—During the last week of the year the Gulf Production Co., in No. 1 Kirby Lumber Co., completed a very good well in the upper part of the Cockfield formation in 8 ft. of sand, approximately 30 ft. below the top of the Cockfield. This sand probably correlates with the so-called Upper Cockfield sand of both the Conroe and Tom Ball fields, with the Pettus sand, and with the upper part of the producing zone at Livingston. This well made 62 bbl. of pipe line oil (41.5° Bé.) per hour on a ⅜-in. choke from a depth of 5731 ft. The Gulf company has a very large block here, taken on extensive geophysical work. Little is known yet of the extent, character of the structure, or of the amount of producing sand, so it is impossible to gage its significance beyond saying that probably it will be an important contribution to the Coast's galaxy of fields.

Garwood.—Although a small gas well was brought in within the Garwood area in southwestern Colorado County in 1932, the Plymouth Oil & Gas Co., in its No. 1 Ream, 1½ miles southwest of this gas well, completed, at a total depth of 6203 ft. in 13 ft. of broken sand, a well that made as much as 400 bbl. of 44° Bé. gravity oil for a few days. However, the well very soon went to water and was abandoned. This sand occurs 339 ft. below the top of the Cockfield, or 67 ft. below the top of the Upper Saline Bayou of Claiborne age. The discouraging thing about this area is the relative lack of any definite structure.

Raisin.—In May, 1933, the Stonleigh Oil & Gas Co., in its No. 1 Terrell, in western Victoria County, 6 miles southwest of Victoria, in a section of broken sand between 4395 and 4437 ft., tested 35 million ft. of gas with a slight spray of condensate. At the end of the year the well was making, with the gas, about 5 or 10 bbl. of 26° Bé. gravity oil. This sand is near the base of the Frio formation. One additional gas well has been completed in this area from this sand, although gas is also indicated in a 2200-ft. sand occurring near the base of the Oakville.

Premont.—The Magnolia Petroleum Corporation in No. 2 Seligson, in southern Jim Wells County, completed a small producer from 4235 to 4253 ft., making 80 bbl. of 23° Bé. pipe line oil daily. This area is about 5 miles northwest of Premont and the sand is of Miocene age.

Louise.—A rather active campaign has been conducted by the Pure Oil Co. during the year in southwestern Wharton County, about 3 miles southeast of Louise. Its No. 1 Stewart showed oil in the latter part of 1932 in a sand from 5966 to 5976 ft. but was not successfully completed at that time, and the well was carried to 8015 ft., where it was plugged back and a producer made that yielded 235 bbl. of oil of 36.6° Bé. gravity oil per day with 1.5 per cent water. This sand lies a little above the middle of the Frio formation. This well, however, was not the first commercial well in the field. The first well actually completed was Pure Oil Company's No. 1 Kountz, in November, 1933, from a sand between 7128 and 7143 ft. very close to the base of the Frio, producing 200 bbl.

of pipe line oil daily on a ½-in. choke. The gravity of this oil was 46.6° Bé. Shortly after completion salt water appeared. Prior to the completion of this well Pure Oil Company's No. 1 Houston, about ⅔ mile southeast of No. 1 Stewart, while being brought in blew out and caught fire. While being placed under control it made as much as 500 bbl. of oil daily, with considerable water. This production is coming from a third sand between 6441 and 6451 ft., and also in the Frio, approximately 700 ft. above its base.

New Sands and New Producing Areas around Old Fields

A number of new areas and new producing sands have been brought into the spotlight during the past year. Perhaps the most active is that on the south side of Hull where the Mirimar Oil Co., in No. 1 Phoenix Development Co., completed a well flowing 2000 bbl. of 35.3° Bé. oil through a ½-in. choke from a sand section between 3960 and 4344 ft., lying within the Upper Saline Bayou formation of the Claiborne series. As many as 13 rigs were active here at the end of the year.

During the year the Texas Company enlarged the boundaries of the Manvel field. A new sand was discovered in Natali No. 1 between 5093 and 5160 ft., approximately 160 ft. below the top of the Heterostegina, which made 42 bbl. of 28.2 Bé. gravity oil through a ⅜-in. choke per hour. The Texas Company's No. 3 Ewing was completed in a Miocene sand from 3870 and 3889 ft., which made 16 bbl. of 25.1° Bé. oil on a ⅜-in. choke.

In Bee County, Grisham et al. completed No. 1 Hatch, 3000 ft. west of the Tuleta field, at a depth of 4575 ft. in the Upper Saline Bayou formation of Claiborne age. This well made as high as 300 bbl. for a day or two but has since been abandoned.

The Amerada-Rycade completed No. 3 Seaburn on the east side of Stratton Ridge, and on the east side of a separate spine of the salt mass, which is known as East Stratton Ridge. This well made 53 bbl. of pipe line oil of 29.2° Bé. gravity on a ½-in. choke, but after a few days salt water appeared and the prospects of the area have dwindled considerably.

The Texas Company's No. 1 Orange National Bank was completed from a new sand at Port Neches from 4767 ft., flowing 360 bbl. of 26.5°Bé. oil with 80 per cent water through a ¼-in. choke. This well is 3300 ft. south of the nearest production in the old part of the field to the north.

In the O'Connor field in southwestern Victoria County, the Humble Oil & Refining Company's No. 10 O'Connor was completed in a new sand for this field from 3045 to 3103 ft., flowing 195 bbl. of 22.5° Bé. oil in 10 hr. on a ½-in. choke.

At Keeran Gulf Production Co., No. 3 Keeran encountered a new sand in the Frio between 5701 and 5705 ft., which flowed 684 bbl. of 35° Bé. oil on a 5/16-in. choke.

Cranfill & Reynolds' No. 10 Moore's Bluff was completed in a sand between 7002 and 7077 ft. in the top of the Claiborne, flowing at the rate of 300 bbl. daily on a ⅜-in. choke, for a short time, with considerable gas. The gravity of the oil was 31.6° Bé. However, the well did not hold up and it was soon carried into salt at 7238 feet.

Of considerable interest was the Republic-Houston No. 4 Ariola Fee, on the north side of the Ariola dome, which blew uncontrolled for a day or two from a sand between 4130 and 4220 ft. in the Middle Oligocene. The well is estimated to have made more than 7000 bbl. per day and 25 million cubic feet of gas while out of control.

Approximately 2 miles southeast of Nome, in northeastern Jefferson County, the Sun and Shell, in their joint test on the Paggi property, showed oil and gas from 6005 to 6031 ft. in the lower part of the Middle Oligocene. It was impossible to complete the well as a commercial producer but the showings were such that possibilities for a field in this area are indicated.

Other Developments

During the year on the Coast of Texas two areas previously suspected to be underlain by salt were proved as salt domes. One of these was the Esperson dome, in Liberty County, where Cranfill & Reynolds' No. 10 Moore's Bluff found salt at 7238 ft., and the other was at Carlos, near the center of the west edge of Grimes County. Here the Humble Oil & Refining Co., in No. 1 Templeman, found anhydrite at 3849 ft. and salt at 4038 ft.

During the year the Conroe field has been steadily developed on the basis of one well to 20 acres, until now there are over 650 producing wells in the field and the area proved producing is greater than 17,000 acres. Very little of it remains yet to be developed. The Thompsons field in Fort Bend County has also been practically entirely developed and its area is indicated to be greater than 3200 acres.

At Hockley John Deering, No. 2 Warren on the northwest, encountered sand from 2419 to 2429 ft., which initially produced 250 bbl. of 30 Bé. oil, by heads, from the lower part of the Miocene. This is the first commercia production at Hockley in some time. Later developments have not yet extended the area.

At Fannett, Mykawa, Genoa and Buckeye, development has been in progress with little change in the status of these fields.

Gas Discoveries

During the year the reserves of gas have been greatly augmented on the Gulf Coast as new areas, probably associated with very deeply buried salt domes, have been brought to light. Tom Ball, Livingston,

TABLE 1.—*Oil and Gas Production in Texas Gulf Coast*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Agua Dulce, *Nueces*	4	20	1,420	1,440	30,107	3,472	8,099	31
2	Allen, *Brazoria*	7	10		10	70,755	5,079	3,044	10
3	Ariola, *Hardin*	2	50		50	198,849	7,630	191,219	1,116
4	Barbers Hill, *Chambers*	18	485		485	37,713,047	7,458,145	8,026,038	17,919
5	Batson, *Hardin*	31	430		430	36,090,792	294,599	207,835	535
6	Big Creek, *Ft. Bend*	11	195		195	7,876,184	425,952	408,801	1,001
7	Blue Ridge, *Ft. Bend*	15	325		325	9,028,755	350,573	287,949	937
8	Boling, *Wharton, Ft Bend*	9	167		167	4,390,455	190,769	125,037	289
9	Brenham, *Austin, Washington*	19	55		55	313,311	20,461	11,849	39
10	Buckeye, *Matagorda*	2	50		50	377,966	105,455	272,511	279
11	Clay Creek, *Washington*	6	230		230	2,627,582	363,352	321,103	706
12	Cleveland, *Liberty*	[1]	50		50				
13	Conroe,[2] *Montgomery*	2	16,934	100	17,034	24,090,872	2,572,416	21,518,456	55,003
14	Damon Mound, *Brazoria*	19	270		270	8,605,452	236,453	260,519	543
15	Esperson, *Liberty*	5	213		213	2,668,142	527,078	485,795	1,049
16	Fannett, *Jefferson*	8	34		34	1,153,432	152,813	145,628	473
17	Goose Creek, *Harris*	26	1,066		1,066	72,021,590	1,291,572	1,159,619	2,710
18	Greta, *Refugio*	1	4,275		4,275	1,216,624		1,216,624	7,517
19	Hankamer, *Liberty*	5	153		153	2,604,471	687,555	539,283	974
20	High Island, *Galveston*	12	177		177	5,741,347	1,507,926	2,467,904	6,000
21	Hockley, *Harris*	2	10		10	14,066	938	13,128	8
22	Hull, *Liberty*	16	690		690	74,183,780	1,912,481	2,006,200	7,712
23	Humble, *Harris*	29	2,322		2,322	117,654,646	2,229,687	1,786,620	3,941
24	Keeran, *Victoria*	2	50		50	141,520	45,458	96,062	205
25	Kingsville, *Kleberg*	11	90		90	592,336	27,828	25,844	68
26	Livingston, *Polk*	1	500	100	600	412,267	392	412,267	2,857
27	Lost Lake, *Chambers*	5	63		63	619,640	131,069	79,821	178
28	Lucas, *Live Oak*	3	50	4,000	4,050	54,579	25,834	19,614	50
29	Manvel, *Brazoria*	3	575		575	818,453	159,082	587,719	1,837
30	Markham, *Matagorda*	26	177		177	4,477,901	529,475	375,339	908
31	Moss Bluff, *Chambers*	4	10		10	179,235	39,862	6,069	
32	Mykawa, *Harris*	4	75		75	282,823	101,104	98,199	144
33	Nash, *Ft. Bend, Brazoria*	8	120		120	1,610,785	52,464	30,048	20
34	North Dayton, *Liberty*	29	55		55	2,090,565	110,674	56,630	161
35	Orange, *Orange*	21	400		400	31,187,401	487,325	333,643	767
36	Orchard, *Ft. Bend*	8	80		80	2,228,850	487,295	413,623	1,054
37	O'Connor, *Refugio, Victoria*	2	250		250	45,144	24,080	21,064	137
38	Pettus, *Bee*	4	1,450		1,450	7,104,402	1,836,020	1,211,928	2,354
39	Pierce Jct., *Harris*	13	312		312	26,841,590	1,832,559	1,559,047	3,250
40	Pledger, *Brazoria*	2	20		20	15,906		15,906	46
41	Pt. Neches, *Orange*	5	75		75	2,312,482	537,725	388,077	923
42	Raccoon Bend,[3] *Austin*	6	1,371	785	2,156	11,944,614	1,771,323	1,501,449	3,295
43	Refugio, *Refugio*	6	1,877	2,720	4,597	28,967,421	3,501,073	2,123,414	4,069
44	Rockland, *Jasper*	5	20		20	26,626	5,204	3,967	6
45	Saratoga, *Hardin*	33	500		500	27,120,342	322,820	298,235	809
46	Saxet, *Nueces*	4	375	1,660	2,035	1,538,473	496,560	876,063	2,044
47	Slick, *Goliad*	4	25		25	52,289	27,605	10,504	21
48	Sour Lake, *Hardin*	32	855		855	76,307,764	620,762	476,017	1,144
49	South Liberty, *Liberty*	9	235		235	14,448,001	390,966	260,627	549
50	Spindletop, *Jefferson*	33	504		504	120,080,770	1,307,315	1,157,944	2,292
51	Sugarland, *Ft. Bend*	6	1,163		1,163	18,851,123	3,485,606	2,538,313	5,556
52	Thompsons, *Ft. Bend*	3	3,031		3,031	9,880,916	4,194,140	4,929,620	9,942
53	Tom Ball, *Harris*	1	8,500	3,900	12,400	245,230		245,230	1,483
54	West Columbia, *Brazoria*	19	265		265	76,767,665	1,332,915	1,198,316	2,594
55	White Point, *San Patricio*	4	20	2,735	2,755	51,256	19,023	16,200	37
56	Other fields					7,375		7,375	
	Total		51,304	17,420	68,724	875,975,869	44,247,964	62,837,435	157,592

[1] Discovery late in December, 1933. See text.
[2] Character of gas: 1128 B.t.u. per cu. ft.; 1 gal. gasoline per M. cu. ft.
[3] Character of gas: 1000 B.t.u. per cu. ft.; 0.8 gal. gasoline per M. cu. ft.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Number of Oil and/or Gas Wells							Average Depth, Ft.	
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
1	15,054	108	15	18	1	0	0	2	12	14	4,897[4]–2,005[5]	4,883[4]–1,998[5]
2	7,075	71	10	4	0	0	0	1	0	1	5,210	4,350
3	3,977	50	279	4	3	0	0	4	0	4	4,250	4,150
4	77,759	1,037	148	316	21	53	0	120	0	120	2,150[6]–5,000	1,900[6]–2,200
5	83,932		4	974	0	29	0	132	0	132	850	200
6	40,394	1,616	56	63	2	0	0	18	0	18	3,850	2,650
7	27,781	463	27	156	2	2	0	34	0	34	3,600	2,400
8	26,290	438	5	125	0	0	0	65	0	65	1,375	420
9	5,697	570	1	54	0	0	0	34	0	34	225	190
10	7,560	126	279	2	1	1	0	1	0	1	7,926	7,831
11	11,424	168	29	37	1	4	0	24	0	24	1,250	985
12				1	1	0	0	1	0	1	5,731	5,725
13	1,423	36	83	685	587	0	0	680	5	685	5,150	5,000
14	31,872	741	17	113	2	0	0	32	0	32	2,700	1,350
15	12,526	391	42	35	2	2	0	26	0	26	2,970	2,185
16	33,924	393	78	12	3	0	0	7	0	7	4,660	3,260
17	67,562	1,778	30	769	1	28	0	92	0	92	2,800	1,050
18	285	12	107	93	93	0	11	82	0	82	4,390	4,350
19	17,023	709	75	15	0	0	0	13	0	13	3,975	2,675
20	32,427	649	167	52	12	2	1	37	0	37	4,325	2,700
21	1,406	47	8	3	1	0	0	1	0	1	2,250	2,220
22	107,513	1,654	50	629	28	48	0	157	0	157	2,900	900
23	50,699	845	16	1,641	2	0	0	245	0	245	1,800	700
24	2,830	283	102	4	2	0	0	2	0	2	5,675	5,150
25	6,582	329	8	18	0	0	0	7	0	7	2,350	2,050
26	825	46	205	14	13	0	0	13	0	13	4,330	4,260
27	9,836	109	20	11	0	0	0	9	0	9	2,750	2,390
28	1,092	58	17	27	0	0	0	3	20	23	4,723[4]–2,125[5]	3,560[4]–2,020[5]
29	1,423	37	204	9	6	0		9	0	8	4,520	3,880
30	25,299	550	38	121	3	1	0	24	0	24	1,500	530
31	17,923	543		5	0	5	0	0	0	0	5,850	5,800
32	3,771	118	48	5	0	3	0	2	0	2	4,850	4,170
33	13,423	224	20	24	0	3	0	1	0	1	4,300	3,700
34	38,010	1,188	20	60	0	0	0	10	0	10	750[6]–3,800	425[6]–2,520
35	77,969	2,599	18	291	0	1	0	50	0	50	4,000	2,850
36	27,861	995	132	22	2	5	0	5	0	5	6,750	2,830
37	177	90	68	4	3	1	0	3	0	3	3,100	2,100
38	4,899	408	40	107	11	15	4	51	2	53	3,900	3,840
39	86,031	1,956	54	191	3	3	0	61	0	61	4,300	3,300
40	795	78	46	1	1	0	0	1	0	1	6,800	6,750
41	30,833	1,186	92	12	2	1	0	9	0	9	3,550	3,140
42	8,712	484	46	145	4	0	19	84	5	89	3,400	3,075
43	15,433	514	37	359	1	9	7	105	44	149	5,000	3,150
44	5,327	133	2	8	0	2	0	3	0	3	1,275	1,260
45	54,241	*x*	5	738	0	8	0	179	0	179	1,000	200
46	4,102	256	63	62	15	2	10	29	11	40	4,600	2,740
47	2,092	209	21	3	0	0	2	1	0	1	4,225	4,211
48	89,249	*x*	7	765	0	30	0	171	0	171	900	230
49	61,480	1,537	11	275	1	10	0	49	0	49	3,500	510
50	238,255	7,446	19	1,346	0	2	4	162	0	162	1,000[6]–3,400	900[6]–2,520
51	16,209	203	85	69	1	0	22	40	0	40	3,575	2,800
52	3,260	36	69	151	89	0	0	145	0	145	5,300	4,925
53	29	2	67	26	26	0	5	21	0	21	5,575	5,375
54	289,689	1,159	68	232	0	26	0	39	0	39	3,200	660
55	10,251	256	37	35	1	0	1	1	18	19	4,902[4]–2,350[5]	4,880[4]–1,850[5]
56				3	3	3					4,902[4]–2,350[5]	4,880[4]–1,850[5]
				10,994	956	294	87	3,097	117	3,214		

[b] Footnotes to column headings and explanation of symbols are on page 175.
[4] Oil. [5] Gas. [6] Cap.

TABLE 1.—(*Continued*)

Line Number	Oil Production Methods at End of 1933						Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1933				
	Number of Wells					Injection into Reservoir[d]	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]
	Flowing	Pumping	Gas-lift	Air-lift	Misc.			1932	1933	Maximum	Minimum	Weighted Average		
1	2	0	0	0	0		1,575	1,575	1,575			54	0.022	M
2	0	1	0	0	0		200			28.3	41.3	34.3	0.105	A
3	2	2	0	0	0		440	150	542	35	42	38	0.136	A
4	35	85	0	0	0		296	x	260	17	34.7	25	0.214	A
5	0	132	0	0	0		x			20	29.9	27.7	x	A
6	1	17	0	0	0		400			42.7	19.5	28	x	A
7	3	31	0	0	0		385	x		19.4	45.1	26	0.25	A
8	0	65	0	0	0		x			21.3	33.7	28.3	0.41	A
9	0	34	0	0	0					14	19	17	x	A
10	1	0	0	0	0		1,045					37.9	0.07	A
11	0	24	0	0	0		80					26	0.36	A
12	1	0	0	0	0		x		940			41	x	M
13	677	1	0	0	2		750±	619	673			37.6	0.05	M
14	0	31	0	1	0		x			21	33	26	0.372	A
15	0	26	0	0	0		100			20.7	31.8	24	0.26	A
16	0	7	0	0	0		540			26	37	30	x	A
17	1	87	0	4	0		x			19.2	36	23	0.19	A
18	79	0	2	0	1		900		777			24.5	0.20	A
19	6	7	0	0	0		424	200±	55	15.7	26.1	23.4	0.33	A
20	24	13	0	0	0		527	x	345	23	39.1	33	0.28	A
21	0	1	0	0	0		40			22	37	32	x	A
22	27	130	0	0	0		x	x	410	17	41	32.7	0.28	A
23	0	245	0	0	0		x	x		17	45	36.2	0.108	A
24	2	0	0	0	0		937	x	750			46.6	x	A
25	0	7	0	0	0		x					19.2	0.14	A
26	13	0	0	0	0		787		556			40.7	0.053	M
27	0	9	0	0	0		490			18	23.4	22.4	0.22	A
28	1	1	1	0	0		x	400	400	24	50	36	x	A
29	8	1	0	0	0		343	x	339	22.5	33	26	x	A
30	2	22	0	0	0		x			23	27.5	23.2	0.21	A
31	0	0	0	0	0		280					29.7	0.21	A
32	0	2	0	0	0		120			27	29	28.2	0.141	A
33	0	1	0	0	0		800			20	24	22	x	A
34	0	10	0	0	0		400			22	41.5	28	0.12	A
35	0	50	0	0	0		x			20.4	27.4	23.8	0.18	A
36	2	3	0	0	0		375	50±	40±	22.1	41.4	28.3	x	A
37	3	0	0	0	0		365					24.0	0.16	A
38	9	20	12	0	10		236	150±	30	45	49	47	0.05	M
39	5	56	0	0	0		355	x	126	21.1	41.5	27.6	0.173	A
40	1	0	0	0	0		2,450	2,450	2,450			55.8	x	M
41	1	8	0	0	0		155	x		19.6	26.5	22.3	0.26	A
42	3	81	0	0	0	[8]	275	x	x	16	32	28	0.18	A
43	46	[7]	54[7]	0	5		[10]	410±	350	23	60	[11]	[12]	A
44	0	3	0	0	0							21	0.26	A
45	0	179	0	0	0					16	22	20	x	A
46	20	0	9	0	0		745	x	620	23	26	25	0.18	A
47	0	0	1	0	0		430	x	65			48.6	0.044	M
48	0	171	0	0	0		x			16	31	22	0.94	A
49	0	1	48	0	0		50			20.5	47	24	0.18	A
50	1	159	1	1	0		400±			41.7	23	28	0.24	A
51	37	1	1	0	1	[9]	475	312	320			27.9	0.31	A
52	145	0	0	0	0		750	650±	568			25	0.20	A
53	20	0	1	0	0		860		1,140	37.5	45.4	41	0.041	M
54	3	33	0	3	0		x	x		18	32	28	x	A
55	1	0	0	0	0		1,425		1,450			31	0.094	A
56														
	1,182	1,757[7]	130[7]	9	19	25								

[7] For Refugio field, 54 represents the combined number of wells pumping and those producing by gas-lift.
[8] Gas injected through 23 wells.
[9] Gas injected through 2 wells.
[10] Shallow, 550 lb.; deep, 1700 lb.
[11] Light oil, 38.8°; heavy oil, 23°.
[12] Light oil, 0.1°; heavy oil, 0.169°.

TABLE 1.—(*Continued*)

Line Number	Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933	
	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.			Name	Depth of Hole, Ft.
1	Frio,[4] Fleming[5]	Olig, Mio	SH, SH	x	14–7	D	7	L. Olig	6,012
2	Mio	Mio	SH	x	100	Ds	30	Mio	5,958
3	Frio	Olig	Ss	x	80	Ds	5	U. Sal. Bayou	6,743
4	Pli, Mio, Frio	Pli, Mio, Olig	Ss	x	75	Ds	126	Vicksburg	8,148
5	Caprock, Lissie, Fleming, Mid. Olig., Yegua	Pli, Mio, Olig, Eoc	Ss, L	x	x	Ds	72	U. Sal. Bayou	5,204
6	Mid. Olig, Frio	Olig	SH	x	25	Ds	53	Vicks	5,536
7	Mid. Olig	Olig	SH	x	60	Ds	98	Vicks	6,024
8	Mid. Olig	Olig	SH	x	60	Ds	231	Mid. Olig	5,546
9	Oakville	Mio	SH	x	10	Ds	47	Sparta	3,572
10	Frio	Olig	SH	x	60	D	1	Frio[13]	8,297
11	Wilcox	Eoc	SH	x	120	Ds	29	Wilcox	5,517
12	Cockfield	Eoc	Ss	x	8	D		Cockfield	5,731
13	Cockfield	Eoc	Ss	27±	40	D	25	L. Sal. Bayou	5,993
14	Mid, Olig, Frio	Olig	SH	x	43	Ds	167	Vicks	4,650
15	Pli, Mio, Mid. Olig, Yegua	Pli, Mio, Olig, Eoc	SH	x	32	Ds	6	U. Sal. Bayou	7,323
16	Mio, Mid. Olig, Frio	Mio, Olig	SH	x	38	Ds	31	Vicks	6,661
17	Pli, Mio, Mid. Olig, Frio, Vicks	Pli, Mio, Olig	SH, Ss	x	38	D	215	Vicks	6,967
18	Heterostegina	Olig	Ss	x	25	D	6	Frio[13]	6,795
19	Mio	Mio	SH	x	24	D	5	Vicks	7,096
20	Pli, Mio, Mid. Olig	Pli, Mio, Olig	S, SH	x	50	Ds	73	Mid. Olig	6,275
21	Frio	Olig	SH	x	30	Ds	63	Caddell	7,063
22	Mid. Olig, Claiborne	Olig, Eoc	S, SH	x	65	Ds	200	U. Sal. Bayou	6,158
23	Mio, Olig, Jackson, Sal. Bayou	Mio, Olig, Eoc	S, SH	x	60	Ds	776	L. Sal. Bayou	8,181
24	Frio	Olig	Ss	x	10	D	3	Frio	7,461
25	Lagarto	Mio	Ss	x	20	D	47	Frio	6,922
26	Cockfield	Eoc		25	18	D	9	U. Sal. Bayou	5,596
27	Frio	Olig	SH, Ss	x	90	Ds	16	Frio	7,471
28	U. Saline Bayou,[4] Gueydan-Frio	Eoc, Olig	SH, Ss	x	15	D	13	U. Sal. Bayou	5,724
29	Mio, Heterostegina, Frio	Mio, Olig	SH, Ss	x	38	D	3	Vicks	7,648
30	Pli, Mio, Mid. Olig	Pli, Mio, Olig	SH, Ss	x	46	Ds	126	Vicks	6,044
31	Marginulina	Olig	SH, Ss	x	33	Ds	53	Vicks	7,375
32	Mio	Mio	SH, Ss	x	32	D	12	Vicks	6,672
33	Mio., Mid. Olig	Mio, Olig	S, SH	x	60	Ds	39	Vicks	6,282
34	Mio, Vicks	Mio, Olig	Ss, SH	x	32	Ds	106	U. Sal. Bayou	5,700
35	Mid. Olig, Mio	Olig, Mio	SH, Ss	x	30	D	53	Mid. Olig[13]	6,158
36	Mio, Frio	Mio, Olig	SH, S	x	28	Ds	24	U. Sal. Bayou	6,757
37	Oakville, Catahoula, Discorbis	Mio, Olig	Ss	x	20	D	5	Frio	6,860
38	Cockfield	Eoc	Ss	x	12	D	29	Queens City	7,569
39	Mio, Mid. Olig, Low. Olig	Mio, Clig	Ss	x	44	Ds	153	Vicks	6,194
40	Frio	Olig	Ss	x	100	D	2	Frio	8,115
41	Pli, Mio	Pli, Mio	SH, S	x	26	D	3	Vicks	6,988
42	Fayette, McElroy	Eoc	Ss	25	18	D	51	U. Sal. Bayou	5,411
43	Mid. Clig, Frio	Olig	S	25±	30	D	98	McElroy	9,134
44	Cockfield	Eoc	Ss	x	10	Ds	7	Cockfield	1,320
45	Mid. Olig, Caprock	Mio, Olig	L, Ss	x	x	Ds	214	U. Sal. Bayou	6,275
46	Mid. Olig, Frio	Olig	Ss	x	16	D	24	Frio	6,479
47	Cockfield	Eoc	Ss	x	10	D	3	U. Sal. Bayou	4,574
48	Caprock-Pli, Miocene-Mid. Olig	Pli, Mio, Olig	Ss, L	x	x	Ds	187	U. Sal. Bayou	6,435
49	Mio, Mid. Olig, Saline Bayou	Mio, Olig, Eoc	SH, Ss	x	40	Ds	111	U. Sal. Bayou	5,176
50	Caprock, Pli, Mio, Mid. Olig, Frio	Pli, Mio, Olig	L, SH, Ss	x	32	Ds	125	Vicks	6,654
51	Mid. Olig	Olig	Ss	25	80	Ds	2	Vicks	4,471
52	Mid. Olig, Frio	Olig	Ss	25	90	D	13	Frio	6,575
53	Cockfield	Eoc	Ss	25	15	D	5	L. Sal. Bayou	7,438
54	Pli, Mio, Mid. Olig, Frio	Pli, Mio, Olig	Ss	25±	250	Ds	162	Vicks	6,270
55	Mid. Olig,[2] Fleming[3]	Olig, Mio	Ss	x	10	D	23	Frio	7,211
56							3,987		

[13] Well drilling on Jan. 1, 1934.

TABLE 2.—*Summary of Drilling Operations in Texas Gulf Coast*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934												Completed during 1933												Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes											Productive Wells	Dry and/or Near-dry Holes											Productive Wells		
	Total Depths, Ft.												Total Depths, Ft.													
	Under 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000	Total	(For Details, See Table 1)	Under 1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000	7,000–8,000	8,000–9,000	9,000–10,000	Total	(For Details See Table 1)	Within Fields	Exploratory
Arkansas	0	2	2	0	0	2	0	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Austin	7	6	7	15	7	4	0	1	0	0	47	199	1	0	0	2	4	1	0	0	0	0	8	4	0	0
Bee	8	7	5	18	26	8	4	0	0	0	76	107	0	0	0	0	4	0	0	0	0	0	4	11	0	1
Brazoria	25	38	22	35	16	7	6	3	0	0	151	391	0	0	0	2	2	2	1	1	0	0	8	10	6	1
Brazos	22	18	6	3	1	0	0	0	0	0	50	0	0	2	0	2	0	0	0	0	0	0	4	0	0	0
Burleson	14	18	18	7	1	0	0	0	0	0	58	0	0	0	2	0	1	0	0	0	0	0	3	0	0	2
Calhoun	0	0	1	0	1	1	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chambers	7	22	5	4	2	4	2	0	0	1	47	332	0	0	1	0	0	1	0	0	0	1	3	26	0	0
Colorado	18	28	5	3	7	4	1	0	0	0	66	1	0	1	0	0	3	2	1	0	0	0	7	1	1	1
De Witt	6	3	6	9	6	1	1	0	0	0	32	0	0	0	1	1	0	0	0	0	0	0	2	0	0	1
Fayette	14	9	13	7	3	0	0	0	0	0	46	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1
Ft. Bend	50	47	11	19	14	5	5	1	1	0	153	461	0	1	1	0	0	2	1	0	1	0	6	96	9	3
Galveston	1	12	0	4	3	0	0	1	0	0	21	52	0	0	0	0	0	0	0	1	0	0	1	12	5	0
Goliad	14	14	5	11	22	4	1	0	0	0	71	3	0	0	0	0	2	0	0	0	0	0	2	0	0	1
Grimes	3	8	12	20	4	2	0	0	0	0	49	0	1	0	1	1	1	2	0	0	0	0	6	0	0	4
Hardin	4	20	8	7	2	0	1	1	0	0	43	2,481	0	1	0	0	0	0	1	0	0	0	2	3	3	0
Harris	22	75	36	42	19	14	15	1	0	0	224	2,635	0	5	2	0	0	4	8	1	0	0	20	34	17	2
Jackson	1	3	6	11	3	0	4	0	0	0	28	0	0	0	0	0	0	0	3	0	0	0	3	0	1	1
Jasper	12	23	2	4	4	0	2	0	0	0	47	8	0	0	0	0	3	0	0	0	0	0	3	0	0	0
Jefferson	16	35	32	28	12	8	7	4	0	0	142	1,359	0	0	1	1	1	0	1	2	0	0	6	3	0	3
Jim Wells	3	2	10	7	5	1	3	0	0	0	31	1	0	0	1	0	0	1	0	0	0	0	2	1	0	1
Kleberg	11	0	0	2	2	0	0	0	0	0	15	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lavaca	26	7	1	2	5	0	0	0	0	0	41	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Liberty	6	23	26	23	11	8	3	0	0	1	101	1,015	0	1	1	0	0	2	2	0	0	1	7	32	17	3
Live Oak	11	30	20	10	9	3	0	0	0	0	83	27	5	11	2	3	0	0	0	0	0	0	21	0	0	4
Madison	5	6	5	0	0	0	0	0	0	0	16	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Matagorda	10	10	10	23	9	5	3	0	0	0	70	127	1	1	1	1	0	1	0	0	0	0	5	4	2	4
Montgomery	15	38	5	16	16	19	0	0	0	0	109	685	0	1	1	0	4	10	0	0	0	0	16	587	28	2
Newton	4	22	3	0	2	0	0	1	0	0	32	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Nueces	0	0	1	11	3	5	2	0	0	0	22	80	0	0	1	0	0	1	2	0	0	0	4	16	1	1
Orange	4	16	2	13	5	0	4	0	0	0	44	303	0	0	0	0	0	0	0	0	0	0	0	2	3	2
Polk	2	8	5	6	10	4	0	0	0	0	35	14	0	0	1	1	7	3	0	0	0	0	12	13	5	1
Refugio	1	0	2	7	3	1	4	0	0	0	18	456	0	0	0	0	1	0	3	0	0	0	4	97	22	2
San Jacinto	2	6	1	1	6	2	0	0	0	0	18	0	0	1	0	0	3	1	0	0	0	0	5	0	0	0
San Patricio	3	1	13	15	9	6	1	0	0	0	48	35	0	0	1	0	0	1	0	0	0	0	2	1	0	1
Trinity	0	10	6	2	2	0	0	0	0	0	20	0	0	1	1	1	0	0	0	0	0	0	3	0	0	1
Tyler	1	12	5	3	2	4	1	0	0	0	28	0	0	0	2	0	0	3	1	0	0	0	6	0	0	0
Victoria	1	4	6	6	4	3	3				27	11											0	2	1	1
Walker	12	16	5	12	0	0	0	0	0	0	45	0	0	1	1	1	0	0	0	0	0	0	3	0	0	0
Waller	9	15	3	10	5	3	0	0	0	0	45	0	0	0	0	0	2	3	0	0	0	0	5	0	0	0
Washington	20	11	12	16	1	1	0	0	0	0	62	37	0	0	1	1	0	1	0	0	0	0	3	1	1	0
Wharton	10	13	3	5	2	3	5	0	1	0	42	125	0	0	0	0	0	1	5	1	0	0	7	0	6	3
Total	400	638	346	437	264	132	79	13	2	2	2,313	10,963	10	27	24	18	38	43	29	6	1	2	198	956	128	47

Louise, Pledger, Greta, the O'Connor-McFaddin area and Raisin have all contributed materially to the gas potentialities of the Texas Coast.

During the year Dick Schwabb completed his No. B-2 Kirby-West near Ace in southwestern Polk County from a depth of 4856 ft., or approximately 150 ft. below the top of the Cockfield, as a gas well containing a very faint trace of oil. Previously Schwabb's No. 1 Kirby-West, 600 ft. northeast of B-2, had topped the same sand series, showing gas at 4748 ft. The well was carried into salt water before a proper test could be made.

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The writer is indebted to John V. Boyce, of the Humble Oil & Refining Co., for assembling and preparing the data appearing in the tables; and to numerous Gulf Coast operators for much information furnished in the preparation of this review.

Oil and Gas Development and Production in North Texas for the Year 1933*

By H. B. Fuqua† and B. E. Thompson,† Fort Worth, Texas

(New York Meeting, February, 1934)

The area discussed herein, commonly known as the North Texas district, embraces the following 10 counties: Archer, Baylor, Clay, Cooke, Foard, Hardeman, Knox, Montague, Wichita and Wilbarger. It is underlain by two major structural features. The northernmost portion of the district, including Cooke, Montague, northern Clay, Wichita, Wilbarger, Foard and Hardeman counties, is underlain by the system of buried mountains known as the Red River uplift, which is parallel to and closely related to the Wichita-Amarillo uplift of Oklahoma and the Texas Panhandle. While the presence of a great majority of the numerous oil fields of the area is traceable to this feature, the production in Archer, southwestern Clay and southeastern Baylor counties is due to the influence of what is known as the Cisco Arch (so called because of its influence on Cisco deposition), the axis of which extends in a northwest-southeast direction across Archer County.

Discussion of Tables

Preliminary to discussing developments during the year 1933, it appears advisable to offer a few words of explanation on Tables 1 and 2, included as part of this paper, in which an effort has been made to summarize oil and gas development in North Texas to Jan. 1, 1934.

One of the chief objectives of this publication is understood to be to show production by individual pools, and, if possible, by distinct pays in a pool. This the authors have been unable to do for North Texas. It is a generally recognized fact that there are well over 100 individual pools, which should perhaps be more properly called "productive spots," in Archer County alone, with perhaps an even greater number in Wichita County. It can be found upon investigation that an apparently continuous productive area covering many acres consists of a half dozen lenticular sands, all stratigraphically different, which produce only under portions of the apparently continuous area. It is also a fact that practically all gross production records are carried by the various interested parties by major districts or by counties. It is obvious therefore

* [Although the authors did not undertake the compilation of this paper until Dec. 26, they have furnished an enormous amount of data. F. A. H., Vice Chairman.]

† Gulf Production Co.

that, in order to secure the desired results in an area in which something like 20,000 oil wells have been completed, an amount of detail work would be required not justified by the value of the results obtained.

Another purpose of the report is to show the number of oil and gas wells and of dry holes by districts or by fields. In carrying out this portion of the assignment the authors have made an accurate check and count of available records. It is unfortunate, however, that numerous shallow wells are present and producing in Archer, Clay and Wichita counties, which, because of lack of interest by major operators, have been disregarded by practically all scouting organizations. While records are not kept of the wells themselves, their production is included in the gross production figures available to the authors; and, since this production cannot be separated, it has been necessary to estimate the number of such shallow producers drilled and also the number of dry holes, in order to make the records check. The number of wells less than 1000 ft. deep that are producing or have produced is believed to be as follows: Archer County, 900 wells; Clay County, 300; Wichita County, 2500. These figures are based partly on records and partly on estimates secured from men well acquainted with the areas covered. By deducting these figures from those shown in the column headed "Number of Oil and/or Gas Wells Completed to End of 1933," the approximate number of oil and/or gas wells over 1000 ft. deep completed to that date will be available.

Developments during 1933

Owing to general economic conditions and to the continued depressing influence of the East Texas field on all other districts, development in

Table 1.—*Oil and Gas Production in North Texas*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres				Total Oil Production, Bbl.			
			Oil	Oil and Gas[a]	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Petrolia,[1] *Clay*	31	500	1,000	4,000	5,500	5,837,000	143,457	118,757	350
2	Worsham, *Clay*	10	100			100	206,000	0	0	0
3	Others, *Clay*		300			300	100,000±	50,000±	50,000±	100±
4	All fields, *Wichita*	22	40,000			40,000	238,132,000	6,081,102	5,709,169	15,951
5	All fields, *Wilbarger*	21	8,710			8,710	49,942,000	3,266,155	2,868,501	8,647
6	All fields, *Archer*	21	20,355			20,355	85,273,000	4,098,692	4,684,375	14,544
7	All fields, *Montague*	11	3,530		500	4,030	18,525,000	1,494,603	1,519,172	4,273
8	Portwood, *Baylor*	9	280			280	1,036,000	160,488	109,499	235
9	All fields, *Cooke*	8	2,000			2,000	7,835,000	577,266	563,382	1,600
10	Thalia, *Foard*	7		100		100	175,659	22,812	24,839	46
11	Johnson, *Foard*	1		100	400	500	56,341	0	56,341	500
	Total		75,775	1,200	4,900	81,875	407,118,000	15,894,575	15,704,035	46,246

[a] Footnotes to column headings and explanation of symbols are on page 175.

[1] For Petrolia field, total gas production in millions of cubic feet: to end of 1933, 97,633,544; during 1932, 543,716; during 1933, 412,782. Gas production data not available for other areas.

North Texas continued at a minimum during the year 1933. However, practically all fields shared in the desultory drilling that was carried on and only nominal changes occurred in the yearly recovery of the various counties from the 1932 figures.

In addition to the limited extension of many producing areas in North Texas and to the development of additional extremely local prolific spots within semiproven areas, two situations of considerable economic importance came to light during the past year; i. e., in the order of their importance, (1) the development of the lime producing area southwest of Archer City in Archer County and (2) the discovery of commercial oil by the Texas Company on the Johnson Ranch in western Foard County.

For several years the Gunsight limestone, which immediately overlies the Swastika-Gose sand zone in Archer County, has been known to carry oil and gas in and adjacent to the Falls County School Land Survey, several miles southwest of Archer City. A number of small wells have been completed in this horizon at a depth of approximately 1200 ft. during the past several years; however, the initial production was extremely low, even after shooting, and operators seldom attempted to make a well out of this limestone unless it proved to be a failure in the underlying sand. During the year 1933 it was discovered that treating these wells with a solution of hydrochloric acid stimulated their production to a marked degree. Instances have been noted in which a limestone that carried only a rainbow show of oil before treatment flowed several hundred barrels daily after the hydrochloric acid had been injected into the well. This discovery greatly stimulated activity in this area, and some-

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Number of Oil and/or Gas Wells								Average Depth, Feet
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[c]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	To Top of Productive Zone
1	3,825	382±	1.1	537	50	5	21	360		43	403	1,500
2	2,060	52±		4	1	0	1	0	0	0	0	3,500
3	333	66±	1.1	100±	100±	0	0	100	0	0	100±	1,000
4	5,950	298±	1.7	10,613	33	104	183	7,223	0	0	7,223	1,500
5	5,730	257±	6.3	1,742	22	17	10	1,305	0	0	1,305	1,700
6	4,221	603±	4.4	5,051	221	52	84	3,533	0	0	3,533	1,000
7	5,220	261±	6.2	706	5	6	4	677	0	29	706	1,000
8	3,700	370±	6.2	56	0	0		42	0	0	.42	1,400
9	3,918	392±	5.9	329	2	11	6	264	0	2	266	1,200
10	1,757	79±	7.0	6	0	0	0	5	0	1	6	2,000
11	563	112±	500.0	2	1	0	0	0	1	1	2	3,800
				19,146	444	195	309	13,509	1	76	13,586	

where in the neighborhood of 100 wells were completed as producers during the year 1933, with probably 50 more drilling at the end of the year. The activity, instead of diminishing, appears to be increasing at the present time.

The Texas Co. drilling its No. 3 Johnson well on an old prospect in western Foard County, which was already known to yield gas, carried its well through the known gas horizon and encountered a highly prolific oil pay in limestone at a depth of 3571 ft. This well produced as much as 2800 bbl. in 24 hr., and is at present producing more than 500 bbl. daily through a small choke. The producing lime appears to be in the upper Canyon (Pennsylvanian in age) and the well, in addition to proving the structure being tested for commercial production, invites additional prospecting in the general area where like situations, in all probability, exist.

Proration Practice

The allocation of production under state-wide—indeed, nation-wide—proration has had little bearing on the 1933 yield of North Texas. In the State of Texas, by law, wells between specified limits in depth are allowed fixed amounts of production (called marginal well allowance) before being prorated. Since out of the more than thirteen thousand wells still producing in the area only a very few hundred are capable of producing more than their marginal well allowance, it is obvious that the actual potential of North Texas does not differ greatly from what it is at present producing.

Table 1.—(*Continued*)

Line Number	Oil Production Methods at End of 1933: Number of Wells: Flowing	Pumping	Character of Oil Approx. Average during 1933: Gravity A.P.I. at 60°F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Producing Rock: Name	Age[g]	Character[h]	Net Thickness, Average Ft.	Structure[i]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1	0	260		y	36.5	0.15	P	Numerous	Per, Pen	S-	10±	A	400	Cam-Ord	4,289
2	0	0	y	y	43.4	0.47	P	Worsham pay	Pen	LS	40±	D	6	Strawn (Pen)	3,950
3	0	200	y	y	36.5	0.25	P	Numerous	Pen	S	5±	MC	326	Strawn (Pen)	3,985
4	0	7,223	41.8	36.1	39.0	0.30	P	Numerous	Per, Pen	S, L	20±	A, M	7,600	Pre-Cam	3,502
5	0	1,305	38.5	35.5	37.0	0.65	P	Numerous	Per, Pen	S, L	20±	A, D	783	Pre-Cam	3,007
6	54	3,479	40.2	36.8	38.5	0.38	P	Numerous	Pen	S, L	7±	ML	5,113	Cam-Ord	5,750
7	0	677	34.0	24.1	29.0	0.90	P	Numerous	Pen	S, L	20±	A, D	225	Pre-Cam	2,915
8	0	42	37.0	37.0	37.0	0.38	P	Swastika sand	Pen	S	10±	ML	161	Strawn (Pen)	4,265
9	0	264	41.0	23.5	35.0	0.65	P	Several	Pen, Ord	S, L	10±	A, D	334	Pre-Cam	3,790
10	0	6	y	y	39.0	0.20	P	Thalia sand	Pen	S	22±	D	12	Pre-Cam	2,550
11	1	0	45.0	43.0	44.0	0.30	P	Johnson lime	Pen	L	5±	D	5	Pre-Cam	5,003
	55	13,456											14,965		

In North Texas during most of the year 1933 the allowable production was set at a figure approximating 51,000 bbl. per day. Production of all wells making marginal well allowance or less was added together and the total deducted from the allowable of 51,000 bbl. The balance was allocated among all wells capable of making more than marginal well allowance in direct proportion to their potentials.

Outlook for 1934

The outlook for 1934 in the North Texas district appears to be considerably brighter than that for the several years preceding. In Archer County a large proven acreage remains to be developed in the lime producing area southwest of Archer City, and considerable "wildcat" prospecting will also undoubtedly be done in an effort to locate similar areas in the county. The Texas Company's completion in Foard County will, in all probability, stimulate "wildcatting" in adjacent counties as suggested in a previous paragraph. In addition, plans for some exploratory drilling are known to have been consummated in both Montague and Clay counties.

In conclusion, it may be stated that owing to the settled character of most of the production in the North Texas district, the additional drilling to be carried on during the year 1934 and subsequent years practically assures the district of an annual output for many years to come not lower—perhaps higher—than that of the year under review.

Table 2.—*Summary of Drilling Operations in North Texas*
(Figures in body of tabulation represent number of holes.)

County	Completed prior to Jan. 1, 1934								Completed during 1933						Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes							Productive Wells	Dry and/or Near-dry Holes					Productive Wells		
	Total Depths, Ft.						Total	(For Details see Table 1)	Total Depths, Ft.				Total	(For Details see Table 1)	Within Fields	Exploratory
	0–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000			0–1,000	1,000–2,000	2,000–3,000	3,000–4,000				
Archer	1,000±	3,925	177	8	2	1	5,113	5,051	40	106	4	1	151	221	62	54
Baylor	0	128	28	3	2	0	161	56	0	3	1	0	4	0	0	1
Clay	300±	300	112	18	2	0	732	641	13	1	1	2	17	160	2	2
Cooke	0	228	96	9	1	0	334	329	0	8	1	1	10	2	4	3
Foard	0	5	11	13	1	1	31	8	0	0	0	0	0	1	0	0
Hardeman	0	13	5	5	2	0	25	0	0	0	0	0	0	0	0	0
Knox	0	3	4	5	2	0	14	0	0	0	0	0	0	0	0	0
Montague	0	117	90	18	0	0	225	706	1	6	1	0	8	5	4	5
Wichita	2,000±	4,769	812	13	6	0	7,600	10,613	23	24	0	0	47	33	11	4
Wilbarger	0	209	551	21	2	0	783	1,742	2	15	5	0	22	22	4	4
Total	3,300±	9,697	1,886	113	20	2	15,018	19,146	79	163	13	4	259	444	87	73

Oil and Gas Production in North Central Texas

By J. M. Armstrong,* Fort Worth, Texas

Line Number	Field, *County*[1]	Age, Years to End of 1933	Area Proved, Acres, Oil	Total Oil Production, Bbl.			Average Production per Acre, Bbl.
				To End of 1933	During 1932	During 1933	
1	*Brown County*			24,758,181	952,293	849,938	
2	Blake	9	1,000	6,061,429	279,665	236,551	6,061[5]
3	Fry	8	700	7,118,580	201,938	152,140	10,162[5]
4	Byler	7	200	621,524[4]	y	y	3,108[4]
5	Byrd's Store	13	250	340,643[4]	y	y	1,363[4]
6	Childers	6	180	573,367[4]	y	y	3,185[4]
7	Cross Cut	12	2,513	5,484,653[4]	y	y	2,182[4]
8	George	6	190	556,621[4]	y	y	2,921[4]
9	Smith-Ellis	7	450	1,921,444[4]	y	y	4,270[4]
10	Thrifty	6	560	705,528[4]	y	y	1,259[4]
11	*Callahan County*			10,788,812	637,142	615,912	
12	Baum	8	400	629,202[4]	y	y	1,573[4]
13	Hatchett	6	350	701,711[4]	y	y	2,005[4]
14	Isenhower	10	600	1,692,224[4]	y	y	2,820[4]
15	Moutray	7	400	1,563,544[4]	y	y	3,908[4]
16	*Coleman County*			7,256,496	892,325	614,160	
17	Overall	7	250	890,116	102,938	71,565	3,561[5]
18	Burkett Deep	3	100	525,421	192,673	132,721	5,254[5]
19	Burkett Shallow	9	850	1,528,733[4]	y	y	1,799[4]
20	Dibrell	6	170	249,340[4]	y	y	1,467[4]
21	Eastland Pool	5	175	1,506,266[4]	y	y	8,607[4]
22	Gladys Belle		150	327,900[4]	y	y	2,186[4]
23	Jennings	6	86	350,758[4]	y	y	4,079[4]
24	Stewartson	3	50	205,069[4]	y	y	4,102[4]
25	*Comanche County*			500,000±[2]	25,000±[2]	24,000±[2]	
26	*Eastland County*			96,747,497[2]	1,156,064[2]	1,155,856[2]	
27	Desdemona[2]	15	6,000	21,434,197[2]	92,165[2]	82,632[2]	3,573[5]
28	Earnest	14	330	4,681,017[4]	y	y	14,184[4]
29	Hightower	11	230	857,708[4]	y	y	3,729[4]
30	Hilburn	14	400	1,040,675[4]	y	y	2,602[4]
31	Pioneer	14	2,000	4,755,546[4]	y	y	2,378[4]
32	55 leases in Ranger	17	3,433	21,842,410[4]	y	y	6,362[4]
33	*Erath County*			[2]	[2]	[2]	
34	*Fisher County*	5	400	2,663,794	242,414	959,645	6,659[5]
35	*Jones County*	7		5,189,976	474,371	679,721	
36	Noodle Creek	6	1,000	4,874,628	426,820	619,830	4,875[5]
37	*Jack County*			4,848,615	554,238	485,468	
38	North Bryson	6	500	1,793,842[4]	y	y	3,588[4]
39	9 leases in Buttram	7	245	842,515[4]	y	y	3,439[4]
40	*Palo Pinto County*			4,659,292	144,007	127,285	
41	*Runnels County*			220,276	22,710	80,171	
42	*Shakleford County*			24,504,079	1,375,926	1,118,153	
43	Cook	8	1,000	10,898,346	638,153	1,243,700	10,898[5]
44	Hope	10	200	807,975[4]	y	y	4,040[4]
45	Ibex	12	1,250	2,135,140[4]	y	y	1,712[4]
46	Engle	7	220	1,337,974[4]	y	y	6,082[4]
47	Frye	8	115	228,972[4]	y	y	1,991[4]
48	*Stephens County*			123,828,155	1,429,781	1,883,374	
49	5 leases in Binney-Hohertz[3]	17	1,700	4,018,998[4]	y	y	2,364[4]
50	88 leases in Beckenridge	17	3,850	22,445,545[4]	y	y	5,830[4]
51	Curry	13	2,580	8,733,051[4]	y	y	3,374[4]
52	36 leases in Eliasville	15	1,960	12,892,567[4]	y	y	6,578[4]
53	Hart	12	50	379,707[4]	y	y	7,594[4]
54	12 leases in Necessity	15	280	1,297,974[4]	y	y	4,636[4]
55	5 leases in North Ranger	15	120	1,055,422[4]	y	y	8,795[4]
56	*Taylor County*			117,918	22,393	36,730	
57	*Throckmorton County*			2,350,229	259,615 ±	259,615 ±	
58	Woodson Deep	9	260	1,394,896	94,998	140,041	5,365[5]
59	Woodson Shallow	8	120	532,327	33,311	36,730	4,436[5]
60	*Young County*			42,083,030	3,373,318	3,078,865	
61	*North half*			15,777,172	2,134,129	1,998,913	
62	*South half*			26,305,858	1,239,189	1,079,952	
63	Bunger	12	1,000	4,434,344	82,137	85,036	4,434[5]
64	Graham	7	360	1,287,770	135,198	81,119	3,578[5]
65	Kissinger	4	300	1,633,781	373,320	219,395	5,446[5]
66	Herron City	12	500	1,503,313	28,623	20,249	3,066[5]
67	South Bend	16	1,440	9,543,103	264,279	198,493	6,627[5]
68	Moren	10	[6]	1,171,581	51,432	39,879	[6]
69	Total			350,516,350 ±	11,561,597 ±	12,588,723 ±	

[1] There has never been commercial oil or gas production in Coke, Concho, Dallas, Denton, Hood, Mills, Nolan, San Saba, Somerell, Tarrant or Wise counties. A negligible quantity of gas has been produced in Parker County, a small quantity of oil in Haskell County and small quantities of oil and gas in McCulloch County. Total gas production cannot be even estimated. Probably half of the gas was dissipated and only poor records have been kept of that utilized. Value of gasoline from natural gas in some counties has exceeded value of oil.

[2] Parts of Desdemona in Comanche and Erath counties are reported with Eastland.

[3] Partly in Palo Pinto County. [4] To Jan. 1, 1932. [5] To Jan. 1, 1934. [6] Only one well in this pool.

* Geologist, Sinclair-Prairie Oil Co.

Line Number	Average Depth, Approx. Ft.	Average Gravity A.P.I. at 60° F.	Producing Rock			Structure[j]
			Name	Age[g]	Character[h]	
1		36-42	Strawn, Bend	Pen		
2	1,200		Cross Cut sand	Pen	S	MC, N
3	1,375		Fry sand	Pen	S	MC, N
4	1,350		Fry sand	Pen	S	MC, N
5	2,700		Bend	Pen	L	MC, A
6	600		Childers	Pen	S	ML, N
7	1,200		Cross Cut	Pen	S	ML, N
8	1,350		Fry sand	Pen	S	ML, N
9	1,350		Fry sand	Pen	S	ML, N
10	1,350		Fry sand	Pen	S	ML, N
11		39		Pen[7]		
12	1,650		Cross Plains sand	Pen	S	ML, N
13	450		Moutray sand	Pen	S	MC
14	250		Cisco sand	Pen	S	ML
15	730		Moutray sand	Pen	S	ML, N
16		38		Pen		
17	1,000-2,700		Canyon, Strawn	Pen	S	ML, N
18	1,400	42	Cross Cut sand	Pen	S	ML, N
19	360		Burkett sand	Pen	S	ML
20	1,900	40	Gwinnup sand	Pen	S	ML, N
21	1,900	40	Gwinnup sand	Pen	S	ML, N
22	1,300	40	Fry sand	Pen	S	MC
23	1,300		Fry sand	Pen	S	ML
24	1,500		Fry sand	Pen	S	ML, N
25				Pen		
26				Pen		
27	2,600		Desdemonia sand	Pen	S, L	ML, A
28	1,900		Earnest sand	Pen	S	ML, N
29	1,200		Olden sand	Pen	S	ML, N
30	3,300		Bend	Pen	L, S	ML, N
31	2,400		Caddo lime	Pen	L	MC, A
32	3,400		McCleskey	Pen	S	ML, A
33				Pen		
34	3,000	38	Stephens lime	Pen	L	MC, N
35		39	Noodle Creek lime	Pen	L	MC, N
36	2,500	39	Noodle Creek lime	Pen	L	MC, N
37		40		Pen		
38	3,100	40	Bryson sand	Pen	S	ML, N
39	2,000	40	Buttram sand	Pen	S	ML, N
40		40		Pen		ML, N
41	2,600	43	McMillan sand	Pen	S	ML, N
42		38		Pen		ML, N
43	1,170	38	Cook sand	Pen	S	ML, N
44	1,300		Hays Howland sand	Pen	S	ML, N
45	3,500		Caddo lime	Pen	S	ML, N
46	1,200	38	Cook sand	Pen	S	ML, N
47	500	38	Hodges	Pen	S	ML, N
48		39		Pen		
49	1,700	39	Binney sand	Pen	S	ML
50	3,240	39	Caddo lime	Pen	L	MC, A
51	3,200	39	Caddo lime	Pen	L	MC, A
52	3,200	39	Caddo lime	Pen	L	MC, A
53	3,150	39	Caddo lime	Pen	L	MC, A
54	1,900-3,500	39	Strawn, Bend	Pen	L, S	MC, ML, A
55	3,400	39	McCleskey sand	Pen	S, L	ML, N
56	2,400	40	Cisco lime and sand	Pen	S, L	MC, N
57				Pen	S, L	MC, N
58	3,900	40	Caddo lime	Pen	L	MC, N
59	300		Cisco sand	Pen	S	MC
60				Pen[8]		
61				Pen	S, LS	
62				Pen[8]	S, L	
63	2,000		Strawn sand	Pen	S	ML, A
64	1,900-3,700		Strawn and Bend	Pen	S	ML, N
65	2,500		Kissinger sand	Pen	S	ML, N
66	2,000-2,700		Strawn sand	Pen	S	ML, N
67	1,900-4,200		Strawn, Bend[8]	Pen[8]	S, L	ML, A
68	2,400		Kissinger sand	Pen	S	ML, N
69						

[g] Footnotes to column headings and explanation of symbols are on page 175.
[7] About 20,000 bbl. from Ellenburger lime of Ordovician age.
[8] About 1,500,000 bbl. from Ellenburger lime of Ordovician age.

Oil and Gas Development in Texas Panhandle in 1933

By R. H. Lynn,* Bartlesville, Okla., and T. C. Craig,† Amarillo, Texas

(New York Meeting, February, 1934)

During the year 1933, in the Texas Panhandle, 113 oil wells were completed, adding 33,337 bbl. to the daily potential of the field. The field potential on Jan. 1, 1933, as determined by the Texas Railroad Commission, was 149,260 bbl., with a daily allowable production of 41,000 bbl. The potential was raised gradually, until on July 16, 1933, it reached 155,344 bbl. with a daily allowable of 55,000 bbl. This potential and allowable was maintained over a period from July 16, 1933, to Sept. 8, 1933, when the potential was reduced to 136,893, with a daily allowable of 43,727 bbl. Since Sept. 8, 1933, there has been a gradual increase, until on Jan. 1, 1934, the field potential reached 159,740 bbl. with a daily allowable of 42,000 bbl. Of this amount 26,429 bbl. are "marginal oil" and 2682 bbl. are exempt on account of water.

Deepening of Wells

During the year 64 wells were deepened, increasing their total oil production 9631 bbl. per day. Of this amount the Gray County granite wash contributed 9256 bbl. from 57 wells. It has been found in many places that the granite wash carries an additional oil pay from 50 to 75 ft. below sea level. The majority of the wells that were drilled during the early development in Gray County encountered their oil above sea level. When the wells producing from the upper horizon have become unprofit-

Table 1.—*Oil and Gas Production in Texas Panhandle*

Line Number	County	Age, Years to End of 1933	Area Proved, Acres		
			Oil and Gas[a]	Gas	Total
1	*Carson*	12	15,000	187,240	202,240
2	*Gray*	8	39,000	54,440	93,440
3	*Hartley*	5	0	1,280	1,280
4	*Hutchinson*	11	47,000	43,560	90,560
5	*Moore*	7	1,000	312,600	313,600
6	*Potter*	14	0	107,520	107,520
7	*Wheeler*	8	3,500	84,500	88,000
8	Total		105,500	791,140	896,640

[a] Footnotes to column headings indicated by letters and explanation of symbols are on page 175.

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able, they may be made of commercial value again, in many instances, by deepening to the lower pay.

Acid Treating

Between 50 and 75 wells, which either were producing or had produced from one of the dolomite or lime zones, were treated with acid. While the results of acid treating are not as spectacular in this field as in the fields in Michigan and Kansas, a survey of the wells treated shows a satisfactory increase in production.

The most universal method of treating in this field is to use 1000 gal. of hot solution, consisting of approximately 300 gal. of 18° Bé. commercial hydrochloric acid and 700 gal. of water. The acid solution is then weighted with varying amounts of hot oil.

Casing Problem

The most difficult problem confronting engineers and geologists in the Texas Panhandle is the proper setting of the oil string where production is expected in the granite wash. Originally large volumes of gas were encountered in the granite wash above the oil pay. This gas has been greatly depleted in that both the volumes and pressures within this zone decline very rapidly, so that after a few months the gas often completely disappears. If this upper gas and the oil are not separated by casing, the oil, owing to differential pressures, is dissipated laterally into this upper zone, formerly carrying gas, and the production from the particular well declines very rapidly and reduces the ultimate recovery. The oil string of casing should be set below the gas in the granite wash and as near the oil-producing zone as possible without casing off the oil. This is not easily done, as there are few good casing points within the granite wash formation. To date there has not been any solution developed worthy of mention to overcome this very serious problem,

Table 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.				Average Oil Production, Bbl		Total Gas Production, Millions Cu. Ft.			
	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Per Acre to End of 1933[b]	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933
1	19,403,247	1,792,708	1,735,200	4,867	1,293	19.47				
2	89,444,700	11,185,177	10,395,226	23,029	2,293	27.12				
3										
4	99,289,931	4,513,298	4,000,410	10,664	2,112	13.53				
5	2,065,905	406,536	351,971	939	2,065	72.23				
6	33,822	0	0							
7	1,894,973	123,449	149,840	492	541	11.71				
8	212,132,578	18,021,168	16,632,647	39,991			3,914,911[1]	413,886[1]	471,120[1]	1,621[1]

[1] Gas figures are composite for field. These figures are the best available but are subject to correction.

and it should command the constant attention of the petroleum engineers engaged in future operations in this area.

Gas

There were 23 gas wells drilled during the year, with a total open flow of 673,802,485 cu. ft.; 45 depleted oil wells were plugged back for gas, with a total open flow of 349,600,000 cu. ft., increasing the open-flow capacity from 16,085,000,000 to 17,108,402,485 cu. ft. for the entire field.

New Development

Two new areas of production were developed during the year. The Badger pool, in southeastern Hutchinson County, was extended some 4 miles to the northwest. This production occurs in the dolomite, which carries the large volumes of gas higher on the structure. The other new area is in west central Wheeler County, a 1½-mile eastward extension of the Bell area in east central Gray County. This production occurs in both dolomite and granite wash.

Producing Zones

The Panhandle field has been subdivided into pools more for geographical than for geological reasons. A few of these pools are characterized by only one type of producing formation, but it is the general rule for the production to be found in more than one. As wells are drilled, these pools tend to merge into one large pool. Since the oil is found at a horizon that is in close proximity to sea level, as the development progresses downdip production is encountered in the various porous formations as they intersect this nearly flat producing horizon. As a result any one pool may produce from all of the known producing formations.

These producing formations vary in lithological character, which has a very pronounced effect on the size of the wells. Descending in the

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells							Average Depth, Ft.		Oil Production Methods at End of 1933		
	Completed to End of 1933	During 1933		At End of 1933				Bottoms of Productive Wells	To Top of Productive Zone	Number of Wells (Approx.)		
		Completed	Abandoned	Producing Oil Only	Producing Oil and Gas[a]	Producing Gas Only	Total Producing			Flowing	Pumping	Gas Lift
1	467	15	2	99	149	191	439	3,150	3,050	12	234	2
2	1,105	73	10	171	703	152	1,026	3,100	3,000	44	824	6
3	4					4		3,200	2,900			
4	1,352	34	36	486	326	119	931	3,000	2,900	40	771	1
5	92	2	1	6	8	69	83	3,500	3,400	1	13	
6	42					42	42	2,500	2,300			
7	281	12	1	23	23	228	274	2,450	2,350	2	44	
8	3,343	136	50	785	1,209	805	2,799			99	1,886	9

geologic section, the dolomite series is found to be productive of oil on the flank of the structure. Progressing updip, the next formation is the arkosic dolomite or arkosic limestone underlain by granite wash. In Moore County the production is found in a limestone that is probably of the time equivalent to at least a part of the granite wash.

The dolomite series is now considered to be Permian while the granite wash and limestone are Pennsylvanian in age.

Prospective Deeper Production

The oldest formation in which production is obtained in the Panhandle is Pennsylvanian. While very little is known concerning the occurrence of pre-Pennsylvanian sediments in this area to date, it seems to be the prevailing opinion among geologists that there is a very strong possibility that older beds, which are productive elsewhere, will be found beneath the granite wash on the flanks of the main structural feature. Two wells have been drilled, the Phillips Petroleum Co. No. 12 Elva in Hutchinson County and the Shamrock Oil and Gas Co. No. 1A Burnett in Moore County, mentioned elsewhere in this paper, which add evidence to substantiate this theory. Wells have been drilled to solid granite on the top of the structure in each of the present producing counties, eliminating a part of the area for possible deeper production.

The writers believe that there will be extensive exploration work done within the next 12 months in an attempt to discover deeper oil in the Panhandle.

Wildcat Operations

Several wildcat wells were drilled in nonproductive counties in 1933. At this time there are three semi-active and two active drilling wells.

TABLE 1.—(*Continued*)

Line Number	Pressure, Lb. per Sq. In.[2,e]			Character of Oil, Approx. Average during 1933					Character of Gas, Approx. Average during 1933		Producing Rock			Structure[i]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933	
	Initial	Average at End of		Gravity A.P.I. at 60° F.			Sulfur, Per Cent	Base[f]	B.t.u. per Cu. Ft.[3]	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]			Name	Depth of Hole, Ft.
		1932	1933	Maximum	Minimum	Weighted Average											
1	425	353	348	45	32	39	0.6	M	1,094	0.67	[4,5]	Per, Pen	D, Da, GW	Af	33		
2	425	355	335	45	31	39	0.4	M	1,103	0.79	[4,5]	Per, Pen	D, Da, GW	Af	119		
3	425	425	425								[4]	Per	D	Af	11		
4	425	363	325	39	29	35	0.8	M	1,106	0.56	[4,5]	Per, Pen	D, Da, L, GW	Af	33	Ord?	5,333
5	425	420	399	36	30	31	0.8	M	1,056	0.53	[4,5]	Per, Pen	D, L, GW	Af	9	Pen	5,545
6	425	420	419						1,069		[4,5]	Per, Pen	D, GW	Af	12		
7	425	386	374	44	30	35	0.4	M	1,070	0.53	[4,5]	Per, Pen	D, Da, GW	Af	44		
8	3343	136													261		

[2] Pressures are for gas wells and braden-head gas.
[3] Dry gas—30″ at 60° F.
[4] Big Lime series (Wichita-Albany).
[5] Upper Pennsylvanian (undifferentiated).

The Shamrock Oil & Gas Co. No. 1A Burnett, in sec. 359, block 44, H. & T.C. Survey, Moore County, is very interesting geologically, since it has drilled through the granite wash and is in Pennsylvanian sediments at 5545 ft. The Woolsey-Devore No. 1 Oxnard, in sec. 85, block 2, A.B. & M. Survey, Randall County, is now drilling at 4577 ft., and probably will be drilled much deeper before being abandoned. While this well does not show promise of encountering production, it has created considerable interest because there are very few wells of this depth on the south side of the granite ridge.

Natural Gasoline Plants

The manufacturing of natural gasoline has been greatly stimulated by the revision of the laws permitting the unrestricted use of gas from

Table 2.—*Summary of Drilling Operations in Texas Panhandle*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934							Completed during 1933						Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes						Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes					Productive Wells (For Details, See Table 1)		
	Total Depths, Ft.							Total Depth, Ft.							
	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	Total		1000–2000	2000–3000	3000–4000	4000–5000	Total		Within Fields	Exploratory
Armstrong	0	0	2	3	0	5	0	0	0	0	0	0	0	0	0
Bailey	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Briscoe	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Carson	4	8	20	0	1	33	439	0	0	1	0	1	15	8	0
Castro	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Childress	4	4	4	1	1	14	0	0	0	0	0	0	0	0	2
Collingsworth	3	6	5	0	0	14	0	0	1	1	0	2	0	0	1
Cottle	0	1	2	5	1	9	0	0	0	0	1	1	0	0	0
Dallam	1	2	1	2	0	6	0	0	0	0	0	0	0	0	1
Deaf Smith	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1
Donley	0	0	7	1	0	8	0	0	0	0	0	0	0	0	0
Floyd	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0
Gray	3	45	66	5	0	119	1026	1	6	3	0	10	73	48	0
Hale	1	0	1	1	0	3	0	0	0	0	0	0	0	0	0
Hall	3	3	3	0	1	10	0	0	0	0	0	0	0	0	0
Hansford	0	0	2	1	0	3	0	0	0	0	0	0	0	0	0
Hartley	0	2	5	3	1	11	4	0	0	0	0	0	0	0	0
Hemphill	0	0	3	0	1	4	0	0	0	0	0	0	0	0	1
Hutchinson	2	9	20	1	1	33	931	1	0	0	0	1	34	15	0
Lamb	1	0	0	2	0	3	0	0	0	0	0	0	0	0	0
Lipscomb	0	0	0	3	1	4	0	0	0	0	0	0	0	0	0
Moore	1	2	6	0	0	9	83	0	0	0	0	0	2	3	0
Motley	0	0	2	5	0	7	0	0	0	0	0	0	0	0	0
Ochiltree	1	0	1	0	0	2	0	0	0	0	1	1	0	0	0
Oldham	0	4	4	1	1	10	0	0	0	0	0	0	0	0	0
Parmer	0	0	2	0	1	3	0	0	0	0	0	0	0	0	0
Potter	0	3	5	4	0	12	42	0	0	0	0	0	0	0	0
Randall	1	2	1	1	0	5	0	0	0	0	0	0	0	0	1
Roberts	0	1	0	1	1	3	0	0	0	0	0	0	0	0	1
Sherman	0	0	2	2	0	4	0	0	0	0	0	0	0	0	0
Wheeler	13	27	3	1	0	44	274	0	0	0	0	0	12	14	0
Total	38	119	168	48	11	384	2799	2	7	5	2	16	136	88	8

any gas well up to 25 per cent of its open-flow capacity. Where no market for the residue gas is available, it may be released into the air.

There were four new plants constructed, which brings the total number of natural gasoline extraction plants to 41, with two more now under construction. The combined production from these plants for 1933 was 222,855,318 gallons.

Carbon Black

There are 25 carbon black plants now operating and two shut down. The total gas consumed for 1933 was 139,204,595,000 cu. ft., all of which was first processed for gasoline before burning in these plants. Since plant operators exhibit a noticeable reluctance to impart specific information concerning plant recoveries, it is impossible to arrive accurately at the carbon black production figure from the gas consumed, as the amount of carbon black recovered per 1000 cu. ft. of gas varies greatly with the grade produced.

Refineries

The total refinery capacity for the Panhandle is 58,250 bbl. daily. Of this amount 2250 bbl. were added during 1933 by the construction of three new plants. The plants operated in this area are either of the cracking or skimming type and their total runs for the year 1933 were 10,230,412 barrels.

Acknowledgments

The writers wish to express their indebtedness to Messrs. Victor Cotner and H. W. McCue, of the Piney Oil and Gas Co., for their help in the preparation of the data presented in Tables 1 and 2 of this paper.

Oil and Gas Development in Southwest Texas during 1933*

By Olin G. Bell,† Laredo, Texas

(New York Meeting, February, 1934)

Development and exploratory work continued vigorously during 1933 in Southwest Texas and, from a standpoint of new production discovered, the new discoveries probably equal or may even exceed any previous year in the history of this area. While exploratory work has been general over the area much of it has been confined to two localities; namely, northern Duval-southern McMullen counties and Starr County.

A persistent effort has been made to open new productive areas in northern Duval County and the adjacent part of McMullen County, occasioned primarily by the fact that the Government Wells group of fields in northern Duval County have been by far the best fields so far developed in this part of the state, and the possibility of being able to find new fields in the same general area under similar geologic conditions.

This has resulted in the discovery of three new fields, Northwest Government Wells, Moca and Eagle Hill. In addition encouraging shows have been found in North Kohler, Hoffman, Smith-Hunter and the Ignacio areas with the prospect that continued exploratory work will develop some of these prospects into fields.

Wildcatting in Starr County was the continued result of an effort to find a trend of production through the county southwestward from the older Reynosa Escarpment fields in Webb, Jim Hogg and Zapata counties. This same impulse has caused most of the wildcatting in Zapata County.

New Fields

Cuevitas.—During the early part of the year the Sun Oil Co. began some core-drill work on a block of leases in northern Starr County, then in June drilled a test which found production in the McElroy member of the Jackson at 2200 ft. Drilling in this field has continued but the productive area has not as yet been clearly defined. Seven oil wells and three gas wells have been completed. There is as yet no pipe line outlet for this production, hence no productive history of the wells has been

[Although the author did not undertake the compilation of this paper until Dec. 26, he has furnished an enormous amount of data. F. A. H., Vice Chairman.]

* Published by permission of the Humble Oil & Refining Co.

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obtained. The oil wells range from 200 to 800 bbl. initial potential production and the gas wells average about 40 million cubic feet.

Moca.—The Moca field, in the northeastern edge of Webb County, was discovered by a test drilled near a fault in this area. The first well found production at 900 ft. This field lies between the old Leaseholders field discovered in 1932 and later abandoned and the S. R. C. field in northwestern Duval County. This field has developed into a reasonably good shallow producing area. The Duval County pipe line was constructed from this field to a loading rack on the Texas-Mexican Railway near Benavides.

TABLE 1.—*Oil and Gas Production in Southwest Texas*

Line Number	Field, *County*	Age in Years to End of 1933[b]	Area Proved, Acres			Total Oil Production, Bbl.				Average Oil Production, Bbl.	
			Oil	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933	Per Acre to End of 1933[b]	Per Well Daily during Nov., 1933
1	Reiser, *Webb*	25	0	0	0	0	0	0			
2	Jennings, *Zapata*	20	0	320	320	0	0	0			
3	Charco Redondo, *Zapata*	14	336	40	376	128,552	9,407	2,474	11	400	0.07
4	Mirando Valley, *Zapata*	12	115	40	155	597,017	12,957	11,578	31	5,550	1.9
5	Mirando City, *Webb*	12	1,430	0	1,430	8,110,165	254,428	217,734	549	5,665	4.1
6	Carolina-Texas, *Webb*	12	90	770	860	256,025	26,218	24,503	89	2,846	8.1
7	Aviator, *Webb*	11	955	0	955	5,021,925	229,265	198,364	495	5,258	3.8
8	Henne-Winch-Fariss, *Jim Hogg*	9	715	440	1,155	3,249,259	8,228	3,752	24	4,544	8.0
9	Cole, *Duval, Webb*	9	105	4,000	4,105	411,265	69,217	85,304	130	3,917	14.4
10	Randado, *Jim Hogg*	7	733	150	883	3,800,052	183,067	140,767	283	5,184	2.1
11	Chittim, *Maverick*	7	0	320	320	0	0	0	0	0	0
12	Alworth, *Jim Hogg*	7	20	40	60	24,049	3,248	1,686		1,202	0
13	Cuellor, *Zapata*	6	315	0	315	2,311,484	324,254	110,568	188	7,336	3.5
14	Albercas, *Webb*	6	321	0	321	2,319,039	111,318	67,123	124	7,224	3.3
15	West Cole, *Webb*	6	330	640	970	2,558,768	416,424	268,875	618	7,663	10.1
16	Driscoll, *Duval*	6	60	220	280	282,803	66,608	54,168	81	6,396	27.0
17	Kohler, *Duval*	6	170	0	170	367,365	56,208	55,384	148	2,135	16.4
18	Government Wells—Middle, *Duval*	5	340	0	340	2,157,101	326,033	276,295	551	7,704	13.1
19	Cow Hill, *Zavallo*	5	0	1,000	1,000	0	0	0	0	0	0
20	Martinez, *Zapata*	4	0	400	400	0	0	0	0	0	0
21	Roma, *Starr*	4	10	30	40	14,422	4,750	3,720	0	1,440	0
22	Escobas, *Zapata*	4	2,464	0	2,464	4,118,616	1,488,805	895,393	2,074	1,671	9.2
23	S.R.C., *Duval*	3	40	0	40	144,433	53,490	28,633	99	3,605	19.8
24	Government Wells—South, *Duval*	3	690	0	690	3,479,821	1,666,344	709,827	1,369	6,823	42.8
25	Los Olmos, *Starr*	3	160	0	160	251,847	98,793	153,054	325	1,573	5.3
26	Jacob, *McMullen*	2	300	0	300	167,075	44,202	122,873	252	561	16.8
27	Sarnosa, *Duval*	2	335	0	335	548,181	194,599	353,582	865	2,000	34.8
28	Rio Grande City, *Starr*	2	22	0	22	49,438	17,928	31,510	67	2,240	9.5
29	Government Wells—North *Duval*	2	3,000	0	3,000	3,915,345	799,839	3,115,506	7,592	1,628	33.4
30	Laurel, *Webb*	2	221	0	221	475,578	134,365	341,213	263	2,160	8.5
31	Moca, *Webb*	1	27	0	27	100,579		100,579	519	3,718	47.2
32	Government Wells—N. W., *Duval*	1	500	0	500	78,649		78,649	521	315	28.9
33	Cuevitas, *Starr*	1	450	120	570	1,960		1,960	28		5.6
34	Eagle Hill, *Duval*	1	120	0	120	18,622		18,622	279		93.0
35	Total		14,374	8,530	22,904	44,959,435	6,599,995	7,473,696			

Eagle Hill.—The Eagle Hill field in northern Duval County was the result of an effort to find a northward trend of production from the Government Wells group of fields. The first well, drilled on the northwest side of a fault, found production in the Cole sand at 1475 ft. in October of 1933. Since then seven oil wells have been completed and one test, which found gas in the Cole sand, has been carried on down to the Government Wells and Mirando horizons but failed to find commercial production in either of these sands.

TABLE I.—(*Continued*)

Line Number	Total Gas Production, Millions Cu. Ft.			Number of Oil and/or Gas Wells					Oil Production Methods at End of 1933		Pressure, Lb. per Sq. In.[e]		Character of Oil Approx. Average during 1933	Producing Rock		
	During 1932	During 1933	Maximum Daily during 1933	Completed to End of 1933	During 1933		At End of 1933		Number of Wells		Average at End of		Gravity A.P.I. at 60° F.			
					Completed	Abandoned	Producing Oil Only	Total Producing	Flowing	Pumping	1932	1933	Weighted Average	Name[1]	Age[g]	Character[h]
1				15	0	0	0		0	0				2	Eoc	S
2	402.0	570.1	May 0.20	25	1	0	0		0	0	230	251		2	Eoc	S
3				155	0	21	136		0	136			17	2	Eoc	S
4	15.2	8.6	Feb. 0.03	39	0	3	16		0	16	261	275	22	2	Eoc	S
5	1.0			294	0	48	133		0	133	740		22	2	Eoc	S
6	1,324.2	1,185.0	Jan. 4.00	63	2	0	11		0	11	276	260	34	2	Eoc	S
7				210	0	25	130		0	130			22	2	Eoc	S
8	569.2	309.2	Jan. 1.00	191	0	9	3		0	3	199	167	22	2	Eoc	S
9	8,675.0	8,693.0	Feb. 29.30	152	0	6	9		0	9	321	290	22	2	Eoc	S
10	12.4	100.0	Feb. 0.60	189	0	7	134		0	134	62	55	22	2	Eoc	S
11	549.0	844.5	3.5	3	0	1	0		0	0				*x*	Eoc	S
12				10	0	0			0	0			22	2	Eoc	S
13	29.4	13.0	Apr. 0.04	80	0	0	53		0	53	190	305	22	2	Eoc	S
14	283.0	191.0	May 0.80	79	0	16	37		0	37	209	191	22	2	Eoc	S
15	685.3	605.2	Jan. 2.0	99	0	8	56		0	56	313	290	22	2	Eoc	S
16	179.0	182.3	July 0.50	15	0	0	3		0	3	780	797	22	2	Eoc	S
17	2,427.4	2,296.0	Feb. 8.40	72	0	3	9		0	9	319	287	22	2	Eoc	S
18				57	1	1	43		0	43			22	2	Eoc	S
19	113.0	99.0	1.5	7	0	0	0		0					*x*	Eoc	S
20	174.3	349.3	June 1.60	19	5	0	0		0		295	269		2	Eoc	S
21				6	0	0	1		0	1			35	3	Eoc	S
22	106.0			256	23	8	235		0	235	254		22	2	Eoc	S
23				6	1	0	5		0	5			22	2	Eoc	S
24	159.6	316.6	Jan. 1.00	45	8	0	38		8	30	742	680	22	2	Eoc	S
25				81	11	0	61		0	61			22	2	Eoc	S
26				17	10	2	15		0	15			22	3	Eoc	S
27	25.7			28	15	0	23		0	23	56		22	2	Eoc	S
28				7	1	0	7		0	7			27	2	Eoc	S
29	1.4	29.0	June 0.01	258	161	0	240		192	48	705	677	22	2	Eoc	S
30	4.0	233.0	Aug. 1.10	38	28	0	31		0	31	530	365	48	3	Eoc	S
31				12	12	0	11		0	11			22	2	Eoc	S
32				24	24	0	24		24	0			22	2	Eoc	S
33		10.4	Oct. 0.30	10	10	0	7		7	0		800	37	2	Eoc	S
34				8	8	0	7		0	7			22	2	Eoc	S
35	15,736.1	16,035.2		2,570	321	158	1,478		231	1,247						

[b] Footnotes to column headings and explanation of symbols are on page 175.
1, Depleted. 2, Jackson. 3, Claiborne.

TABLE 2.—*Summary of Drilling Operations in Southwest Texas*
(Figures in body of tabulation represent number of holes.)

	Completed during 1933							Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes[1]						Productive Wells (For Details See Table 1)		
	Total Depths, Ft.					Total		Within Fields	Exploratory
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000				
Dimitt						0	0	0	2
Duval	1	3	19	6		29	218	26	6
Frio						0	0	0	1
Jim Hogg			7	1		8	0	1	2
La Salle	1		2	1		4	0	0	0
Maverick						0	0	0	0
McMullen	5	4	15	3		27	10	4	3
Starr	12	3	5	1	1	22	22	4	10
Webb	1	4	10	1	1	17	42	4	2
Zapata	13	15	3			31	29	4	3
Zavalla						0	0	0	1
Totals	33	29	61	13	2	138[1]	321	43	30

[1] Includes only those outside of fields.

Government Wells—Northwest.—The northwest Government Wells field was discovered as a result of wildcatting in an effort to find production along the fault trend through northwestern Duval County. The first well was completed as a gas producer in the Cole horizon, the next one failed to find production in the Cole horizon at 1500 ft. but was carried on down and found production in the Government Wells sand. Development since has shown this to be a field similar to the north field and it now seems probable that production in the northwest and north fields will actually connect. The productive area in this field has not as yet been defined.

DEVELOPMENT OF PROVEN AREAS

Government Wells—North.—The north Government Wells field was discovered in June of 1932 and development has been steady up to the close of 1933. The producing area has not as yet been entirely defined but it is doubtful whether much new producing area is added to it. Development in this field has been systematic and carried on in an orderly manner under definite proration and well-spacing orders of the Texas Railroad Commission.

Government Wells—South.—Development in the south Government Wells field has likewise continued during 1933 but has consisted mainly of steady development toward the north end of the field, and this has indicated that the trend of production is slightly west of the old middle Government Wells field. This development still continues and the northern productive limits of the field are not as yet defined. Here, as in the north field, development has been steady and systematic under

proration and well-spacing orders of the Texas Railroad Commission with a limit on the maximum gas-oil ratio allowed.

Escobas.—The Escobas field in northeast central Zapata County has continued slowly but steadily during 1933 and has consisted of continued drilling in part of the previous proven area and also a continuation of drilling at the north end of the field, which has opened up new producing acreage to the north.

Proration

Except for the Government Wells group of fields, proration did not become generally effective in this area until Sept. 8, of 1933, at which time the Texas Railroad Commission orders placed a maximum allowable on each field in this territory. Actually this new order affected only the Government Wells group of fields and to a slight extent some of the older fields in which some of the wells were still above the marginal well allowance as defined by the Texas law. Thus the Driscoll field, some wells in the Escobas field, etc., were affected. For the remaining fields the maximum allowable set by the Texas Railroad Commission was slightly above the maximum potential of these fields. Thus practically all the wells in these older fields were below the marginal well limit.

Gas Development

Gas withdrawals from the fields in this area during the year continued at a rate slightly below normal to normal. The normal decline in pressure in some of the older fields necessitated many of the wells being at least temporarily shut in although not abandoned and heavier pulls from nearer producing areas. The net withdrawals from the area, however, remained about the same. There was very little new gas development during the year and the reason is that there is much more gas already developed than the American companies need at the present time.

Summary and Prospects

On the whole, therefore, wildcatting during the year gave promise of opening several new producing areas and continued wildcatting during the year will probably definitely find some new producing fields.

Exploratory work during 1934 will probably continue vigorously.

Development and Production in West Texas, 1933

By Colin W. Reith,* Iraan, Texas

(New York Meeting, February, 1934)

The development of production in West Texas during the year 1933 was largely confined to the expansion of proven areas, especially Ward County, Iatan and North Winkler. Wildcat activity was at a comparatively low ebb and resulted only in discoveries of probable minor importance in Ector County.

The interest shown in deep wildcatting to test beds of pre-Permian age was a new development, which should soon throw light on the possibilities of deeper production from the present producing fields. The important pre-Permian tests of the year were:

1. Stanolind Oil and Gas Co., Todd No. 1, a unitized test, in north central Crockett County on a probable continuation of the Big Lake trend. The well encountered several showings of oil and penetrated an Ordovician section very similar to the productive zones at Big Lake, but was abandoned when sulfur water was encountered at 8041 feet.

2. Gulf Production Co., McElroy No. 103, in the McElroy Field, Upton County. The well was drilling at 8553 ft. at the close of the year in beds of probable pre-Permian age. The test is an important one because it should prove or disprove deep production in the Church-Fields-McElroy pools and also throw geologic light on the deep possibilities of other fields in the western part of the Permian Basin.

3. Humble Oil and Refining Co., White and Baker No. 1, in Pecos County, about 11 miles west of the Yates field. The well is on a nonproductive Permian high and should indicate the deep possibilities of the Yates field. At the end of the year, drilling had progressed to 7200 ft., where beds of pre-Permian age are believed to have been penetrated.

The major fields in West Texas, in which present-day proration had its inception, were produced under increased restrictions. A date of importance in the proration history of the area was Sept. 8, 1933, when the Railroad Commission issued an order placing all producing wells under proration. The severe reductions in total outlet made during 1933 were well compensated for by a more than threefold increase in the price of crude oil.

Acid treatment was one of the general engineering developments of interest. The work had not progressed sufficiently at the close of 1933

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* Petroleum Engineer, The California Co.

to predict its outcome; but apparently the results, though conflicting, will warrant acid treating campaigns in several partly depleted fields. Some engineers believe that many flush producers could be treated with acid to reduce bottom-hole differential flowing pressure, gas-oil ratio, and water coning effect. No doubt some work of this kind will be attempted during 1934. The limestone pays in the West Texas fields are usually dolomitic and occasionally sandy, but tests made on cores from various fields have indicated high solubility in many cases.

Pressure drilling with rotary showed additional value, with further refinements in drilling the Ordovician pays at Big Lake, deepening wells with high gas-oil ratio at Yates, and a limited application in drilling through easily watered sand pays in Ward County.

TABLE 1.—*Oil and Gas Production in West Texas*

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres		Total Oil Production, Bbl.			
			Oil	Gas	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Toyah, *Reeves*	14	640		6,000	500	250	2
2	Westbrook, *Mitchell*	13	4,000		6,770,846	411,721	378,336	1,005
	Big Lake, *Reagan*							
3	2,400-ft. pay	10	*y*		2,006,219[1]	150,000±	144,434	357
4	3,000-ft. pay	10	2,500		52,500,063[1]	2,887,774	2,253,807	5,650
5	Ordovician	5	1,200		20,253,463	5,714,777	4,176,324	8,400
6	Emerald, *Garza*	9	480		76,125	7,265	7,128	23
7	Ira, *Scurry*	9	640		98,550	9,490	9,322	26
8	Church-Fields-McElroy, *Crane, Upton*	8	16,120		87,295,839	5,648,998	4,594,468	8,702
	Howard-Glasscock, *Howard, Glasscock*							
9	1,400-ft. pay	7	700		2,655,000	291,894	321,418	650
10	1,700-ft. pay	8	5,000		8,754,452	836,351	825,532	2,090
11	2,200-ft. pay	5	4,000		19,723,816	3,303,034	2,953,733	6,546
12	2,500-ft. pay	6	1,000		4,376,233	625,026	527,147	1,400
13	3,000-ft. pay	6	3,200		17,613,956	1,285,184	931,573	2,331
14	Iatan, *Mitchell, Howard*	8	5,000		1,097,895	202,662	144,024	832
15	McCamey, *Upton*	8	6,500		24,349,000	1,517,911	1,404,980	3,870
16	Wheat, *Loving*	8	4,000		4,312,986	1,125,965	922,751	1,680
17	World-Powell-Grayson, *Crockett, Reagan*	8	3,069		4,273,028	427,604	340,576	605
	Yates, *Pecos*							
18	Lime	7	20,000		180,279,483	22,801,042	20,228,277	41,816
19	Sand	0	700		4,255		4,255	51
20	Toborg	4	1,000		2,011,691	509,849	459,124	1,175
21	Hendrick, *Winkler*	7	9,200	50	167,266,003	10,229,339	7,341,115	17,383
22	Scarborough-Leck, *Winkler*	6	1,860	10	3,846,742	506,132	764,123	1,685
23	Pecos Valley, *Pecos*	5	1,160		374,124	117,121	80,963	247
24	Pryor, *Pecos*	5	160		18,623	6,333	6,760	18
	Taylor-Link, *Pecos*							
25	Lime	5	1,000		2,634,193	274,348	186,145	416
26	Sand	4	450		417,521	36,319	33,833	88
27	Ward County, *Ward*	5	6,150		7,157,089	1,878,712	2,693,743	5,150
28	Irion, *Irion*	4	340		68,630	10,382	7,487	10
29	Penn, *Ector*	3	2,920		9,032,715	1,676,388	1,722,457	5,250
30	Deeprock-Fuhrman, *Andrews*	3	3,000	700	48,000	4,000	14,000	600
31	Cowden, *Ector*	3	3,200		153,753	12,134	107,790	781
32	Addis, *Ector*	1	800		130,156		130,156	402
33	Total		109,989	760	629,606,449	62,508,255±	53,716,031	119,241

[1] Production from 2,400-ft. pay in 10 wells, now deepened to 3,000-ft. pay, is reported with 3,000-ft. pay.

Yates.—A small drilling campaign during the last half of 1933 resulted from the award of vacancy claims on about 400 acres across the heart of the field. Successful efforts to reduce gas production were continued. Eight wells having shallow penetration were deepened with light pressure-rotary equipment, tubed, and gas-oil ratios reduced from several thousand to an average of less than 150 cu. ft. per barrel. If necessary to prevent gas waste all new wells were drilled in under pressure. The adjustment of proration potentials was continued in the ratio of loss of 1300-ft. datum pressure on each well to prevent the gas waste and water coning that would result from open-flow potential tests. The immediate effect of the intensive gas-conservation program of the past two years has been: (1) to reduce the average field gas-oil ratio from 525 to 275 cu.

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.			Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells					
									During 1933		At End of 1933		
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov. 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Completed to End of 1933	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only
1	94	94	*y*					35	0	*y*	*y*	*y*	
2	1,693	34	9					119	0	0	4	113	
3	*x*	*x*	45	*x*	*x*	*x*	*x*	21[2]	0	2	0	8	0
4	21,000	700	27					261	0	27	*y*	208	
5	16,878	42	763	*y*	*y*	*y*	*y*	22	8	0	7	14	
6	158	13	6					12	1	1	0	4	
7	154	6	5					7	0	0	0	5	
8	5,415	27	25	59,094	5,032	3,026	12	343	2	0	1	342	
9	3,792	63	12					52	0	0	0	52	
10	1,750	70	8					260	4	0	0	254	
11	4,930	*y*	163					120	21	0	0	120	
12	4,376	*y*	35					40	0	0	0	40	
13	5,504	*y*	30					88	0	0	0	76	
14	219	4	18					57	15	0	0	48	
15	3,750	125	14					376	1	*y*	*y*	260	
16	1,078	154	25					74	2	0	0	69	
17	1,392	107	17					59	0	1	2	35	
18	9,014	150	99	83,000	7,000	7,000	30	424	16	0	25	399	
19	6	1	26					3	3	0	0	3	
20	2,012	101	16					77	3	0	1	76	
21	18,181	*y*	42	*x*	*x*	*x*	*x*	628	0	28	98	416	5
22	2,122	*y*	44					49	16	4	7	38	1
23	322	*y*	12					21	1	*y*	0	21	
24	116	8	9					3	0	0	0	2	
25	2,634	176	13					47	1	3	7	33	
26	928	155	6					21	0	1	1	14	
27	1,163	46	26					218	77	0	*y*	209	3
28	202	20	1					15	2	0	0	15	
29	3,114	389	65	6,*xxx*	1,845	1,349	4	83	1	1	0	81	1
30	16	1	125					6	1	0	1	5	
31	48	*y*	112					7	5	0	0	7	
32	163	*y*	67					6	6	0	0	6	
33								3,544	186			2,973	10

[b] Footnotes to column heading and explanation of symbols are on page 175.
[2] Ten of these wells have been abandoned in 2,400-ft. pay and deepened to 3,000-ft. pay

ft. per barrel; (2) to reduce the loss in bottom-hole pressure per million barrels of oil produced; (3) to equalize bottom-hole pressures throughout the field; and (4) to level the oil-water contact.

The Yates field went into first place among West Texas fields in the total recovery of oil when in March, 1933, it surpassed the Hendrick field.

The Yates Sand, a shallow pay of minor importance, was first developed during the year. The productive area will be limited to about 700 acres, and the wells will be small pumpers.

Ector County.—Two new productive areas were discovered. Harrison et al. Addis No. 1, approximately 4½ miles west of Odessa, was completed at 3930 ft. in January, 1933, with an initial potential of 445 bbl.

TABLE 1.—(*Continued*)

	Average Depth, Ft.		Oil Production Methods at End of 1933			Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1933				
			Number of Wells				Average at End of		Gravity A.P.I. at 60° F.				
Line Number	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Initial	1932	1933	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	100	100	0	*y*		*x*	*x*	*x*			27	1.73	M
2	3,000	2,900	0	113		1,000	250	*y*	27	25	26	2.52	MA
3	2,500	2,375	0	8	0	*x*	*x*	*x*			35	*y*	*y*
4	3,000	2,970	0	208		*x*	*x*	*x*	*x*	*x*	36	0.36	M
5	8,800	8,500	12	0	2	3,750	*x*	*x*	58	42	46	0.19	P
6	2,600	2,510	0	4		*x*	*x*	*x*	40	38	39	*y*	*y*
7	2,395	2,325	0	5		*x*	*x*	*x*	25	25	25	2.06	M
8	3,000	2,800	46	295	1	725	556	538	33	30	32	2.50	M
9	1,400	1,340	0	52		*x*	*x*	*x*	*y*	*y*	33	1.02	M
10	1,750	1,725	0	254		*x*	*x*	*x*	*y*	*y*	32	0.82	M
11	2,300	*y*	0	120		*x*	*x*	*x*	*y*	*y*	30	1.60	M
12	2,600	*y*	0	40		*x*	*x*	*x*	*y*	*y*	27	3.43	M
13	3,005	*y*	0	76		*x*	*x*	*x*	*y*	*y*	27	2.01	M
14	2,800	2,600	0	48		1,000	680	*y*	32	30	31	1.99	M
15	2,335	2,000	0	260		*x*	*x*	*y*	*y*	*y*	28	1.98	M
16	4,304	4,297	64	5		1,650	*x*	1,500	39	37	38	0.21	PM
17	2,660	2,645	0	35		*x*	*x*	*x*	30	28	29	0.66	MA
18	1,450	1,310	375	24		700	564	547	31	29	30	1.57	M
19	938	890	0	3		110		110	*y*	*y*	32	*y*	*y*
20	445	400	0	76		160	80	60	*y*	*y*	23	1.90	M
21	2,900	2,600	239	177		*x*	*x*	*x*	35	24	28	1.53	M
22	3,425	2,850	29	9		*x*	*x*	*x*	36	28	32	1.30	M
23	1,600	1,300	0	21		*x*	*x*	*x*	*y*	*y*	30	*y*	*y*
24	1,400	1,385	0	2		*x*	*x*	55	24	24	24	0.6	A
25	1,675	1,630	1	32		600	*x*	*x*	31	29	30	1.32	M
26	1,000	970	1	13		275	*x*	*x*	28	28	28	*y*	*y*
27	2,575	2,440	208	1		1,400	1,350	1,250	36	29	32	1.10	M
28	1,410	1,400	0	15		*x*	*x*	*x*	*y*	*y*	40	*y*	*y*
29	3,700	3,590	73	8		1,500	*x*	923	35	32	33	2.6	M
30	4,500	4,425	5	0		*x*	*x*	*x*	26	26	26	*y*	*y*
31	4,300	4,200	6	1		1,640	1,632	1,627	34	30	32	1.7	M
32	4,065	3,930	6	0		1,485		1,480	34	30	32	*y*	*y*
33			1,067	1,905	3								

daily. Five additional wells having smaller potentials have extended the Addis field one mile north and one mile southeast of the discovery well. Broderick and Calvert, Cowden No. 1, approximately 9½ miles west of Odessa, was completed at 4338 ft. in November, 1933, with an initial potential of 214 bbl. daily. The importance of the Broderick discovery will not be known until additional wells are drilled.

The Cowden field, in the northern part of the county, was extended 2½ miles northwest of the discovery well.

Howard-Glasscock.—Development in this field was largely confined to a 1½ mile western extension in Glasscock County (McDowell area) and to 1700-ft. pay drilling in southern Howard County (Chalk area).

TABLE 1.—(*Continued*)

Line Number	Character of Gas Approx. Average during 1933		Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933	
	B.t.u. per Cu. Ft.	Gals. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness Average Ft.			Name	Depth of Hole, Ft.
1				Pli?	SH	Por	1	T	y	Delaware	4,133
2			Big Lime	Per	D, L	Por	50	A	3	Pennsylvanian	5,250
3	y	y		Per	S	20	x	A	y		
4		4.0	Big Lime	Per	D, L	P, C	30	A	0		
5	1,200	0.9	Ellenberger	Ord	L	Car	400	A	2	Ellenburger	9,562
6			Big Lime	Per	S, LS	Por	12	A	7	Permian	4,801
7			Big Lime	Per	D, L	Por	25	A	7	Permian	4,528
8	1,110	1.65	Big Lime	Per	D, L	15	200	A	3	Pennsylvanian	8,553
9			Yates sand	Per	S	Por	60	A	3	Permian	4,393
10				Per	S	22	25	A	3		
11				Per	D, L	Car	y	A	6		
12			Big Lime	Per	D, L	Car	y	A	2		
13			Big Lime	Per	D, L	Car	y	A	13		
14			Big Lime	Per	D, L	Por	50	A	11	Permian	3,250
15			Big Lime	Per	D, L	Car	30	A	9	Permian	4,610
16	1,000	1.00	Delaware sand	Per	S	Por	7	AM	10	Lower Delaware	5,083
17			Big Lime	Per	D, L	Por	13	A	4	Permian	3,206
18	y	1.00	Big Lime	Per	D, LS	Car	60	A	0	Permian	1,883
19			Yates sand	Per	S	Por	15	A	0		
20			Toborg sand	Cre?	S, D	Por	20	AL	5		
21			Big Lime	Per	D, LS	P, C	y	A	26	Permian	3,962
22			Big Lime	Per	D, LS	P, C	y	A	9	Permian	3,436
23			Big Lime	Per	D, L	Por	y	A	y	Permian	1,938
24				Per	SH	Por	15	A	0	Permian	4,375
25			Big Lime	Per	D, L	P, C	15	A	0	Permian	2,185
26			Yates sand	Per	S	Por	6	AL	1		
27				Per	S, D, L	Por	25	A	3	Permian	4,825
28			San Angelo	Per	S	Por	10	T	y	Permian	1,480
29	y	1.75	Big Lime	Per	D, L	P, C	8	A	3	Permian	3,786
30			Big Lime	Per	D, L	Por	25	A	3	Permian	4,700
31	y	0.5	Big Lime	Per	D, LS	Por	y	A	0	Permian	4,627
32	y	0.5	Big Lime	Per	D, LS	Por	y	A	0	Permian	4,278
33											

Iatan.—Considerable drilling activity extended the proven limits of the field 1½ miles west and ½ mile north.

Ward County.—With an average of about 30 wells drilling throughout

TABLE 2.—*Summary of Drilling Operations in West Texas*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934											Completed during 1933									Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes										Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes								Productive Wells (For Details See Table 1)		
	Total Depths, Ft.									Total		Total Depths, Ft.							Total			
	0-1000	1000-2000	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000	8000-9000				1000-2000	2000-3000	3000-4000	4000-5000	5000-6000	8000-9000			Within Fields	Exploratory
Andrews	0	0	0	1	9	2	0	0	0	12	6	0	0	0	0	0	0	0	0	1	1	0
Bailey	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Borden	2	4	2	14	2	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0
Brewster	0	8	7	6	2	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	1
Cochran	0	2	0	0	0	4	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
Cottle	1	0	1	2	4	1	0	0	0	9	0	0	0	0	0	0	1	0	1	0	0	0
Crane	0	1	6	20	6	0	0	0	0	33	323	0	0	0	0	0	0	0	0	0	1	2
Crockett	1	22	28	28	7	1	1	0	1	89	55	0	3	2	0	0	0	1	6	0	0	1
Crosby	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Culberson	13	3	3	11	1	1	0	0	0	32	0	0	0	1	0	0	0	0	1	0	0	2
Dawson	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1
Dickens	0	0	2	2	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Ector	0	2	1	10	11	0	0	0	0	24	96	0	0	0	1	1	0	0	2	12	9	2
El Paso	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1
Floyd	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Gaines	0	0	0	4	4	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	1
Garza	1	0	8	10	2	1	0	0	0	22	12	0	0	1	3	0	0	0	4	1	0	0
Glasscock	0	2	16	34	2	0	0	0	0	54	83	0	0	0	0	0	0	0	0	12	8	2
Hale	6	1	0	1	1	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
Hockley	0	2	0	1	1	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Howard	2	6	5	29	5	0	0	0	0	47	520	0	2	0	0	1	0	0	3	28	10	2
Hudspeth	2	5	2	1	1	0	0	0	0	11	0	0	1	0	0	0	0	0	1	0	0	1
Irion	5	32	7	9	0	0	0	2	2	57	15	1	4	0	0	0	0	0	5	2	2	1
Jeff Davis	1	1	1	3	1	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Kent	2	0	1	4	2	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
King	1	1	0	8	2	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0
Lamb	0	1	0	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3
Loving	2	0	0	2	10	3	0	0	0	17	74	0	0	0	1	2	0	0	3	2	3	0
Lubbock	2	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Lynn	1	1	1	1		1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Martin	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Midland	0	0	1	1	7	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
Mitchell	13	5	4	43	3	1	0	0	0	69	133	0	0	0	0	0	0	0	0	0	0	0
Motley	2	0	1	2	5	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Pecos	14	115	75	30	9	1	0	0	0	244	596	0	2	3	0	0	0	0	5	24	15	2
Presidio	3	1	0	2	1	1	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	1
Reagan	0	1	11	48	1	0	0	0	0	61	298	0	0	0	2	0	0	0	2	8	9	2
Reeves	6	8	4	12	10	2	0	0	0	42	35	0	0	0	0	1	0	0	1	0	0	2
Schleicher	2	0	0	3		2	3	0	0	10	0	0	0	0	0	0	0	0	0	0	0	1
Scurry	5	2	1	11	5	1	0	0	0	25	7	0	0	0	1	0	1	0	2	0	0	3
Sterling	4	8	4	19	1					36	0								0	0	0	1
Stonewall		2	1	6	1					10	0								0	0	0	0
Sutton	2	2		1	4					9	0								0	0	0	0
Terrell	4		3	5	2	2				16	0								0	0	0	2
Terry						2				2	0								0	0	0	0
Tom Green	23	19	4	10	1					57	0	1							1	0	0	1
Upton	1	1	28	26	5					61	396								0	3	0	1
Val Verde	1		7	8	2		2			20	0								0	0	0	1
Ward	7	1	35	11	3	2				59	218			12	1				13	77	27	2
Winkler	1		3	24	4					32	677								0	16	6	1
Yoakum	2				1					3	0								0	0	0	0
Total	132	259	275	467	146	29	6	2	3	1319	3556	2	12	19	9	5	2	1	50	184	91	40

the year, the county was by far the most active in West Texas. The proven area of sand pays in the southeastern part of the county was extended considerably. The discovery of a 3000-ft. lime pay in Abell, Shell-Sloan B No. 1, sec. 16, block 5, H. & T.C. Survey, was of interest. A consistent drilling program was continued in the O'Brien pool in the northern part of the county. There are 6150 proven acres in the county, and the semi-proven acreage is roughly twice as much.

Hendrick.—The field is in its period of decadence. Although more than half of the producing wells are flowing, approximately 97 per cent of the fluid produced is water. Production methods are confined to lifting the greatest possible volume of water in order to obtain the associated oil. Some wells that produce nothing but water are operated because the oil production of adjacent wells is thereby increased.

Scarborough-Leck.—The proven limits of the field were extended by the 16 producers completed during the year.

Andrews County.—Added impetus will be given to development in the county by the completion of a pipe line outlet in November, 1933.

Big Lake.—Deep drilling extended the Ordovician productive area approximately ½ mile northwest and ¼ mile southeast.

All deep wells completed during the last half of 1933 were drilled in with pressure-rotary equipment. The gas cap penetrated is from 200 to 400 ft. thick; the pressure within the cap is about 3000 lb. per sq. in. While drilling in, the wells are produced with surface pressures on the returns of from 500 to 1600 lb. per sq. in. At 8500 ft., flowing pressures of producing wells vary between 2000 and 2900 lb. per sq. in., depending on the permeability of the pay zone. Shut-in reservoir pressures are estimated to range from 2800 to 3300 lb. per sq. in., with the higher pressures in the direction of newer development. The gas solution ratio of the heavy (44° A.P.I.) oil was between 1300 and 1700 cu. ft. per barrel. This was determined after the heavy oil had been positively isolated in the lower portion of the reservoir below the water-white gas-cap oil.

Two wells were placed on gas-lift during the year. The gas supply is derived mostly from the new heavy-gravity oil wells with separators operating under from 1200 to 1400 lb. per sq. in. pressure.

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Oil and Gas Production in Utah

By E. S. Shaw,* Denver, Colo.

(New York Meeting, February, 1934)

Utah continues as a very unimportant factor in oil and gas production. During the year 1933 there were no developments of noteworthy significance. There were no completions of either producers or dry holes during the year. The only commercial production in Utah has been from the five fields listed in Table 1 and mentioned briefly in the following paragraphs.

Virgin Field.—Oil was first discovered in 1907 in a well drilled in sec. 13, T.41S., R.12W. Of the first 15 wells drilled, all but three were failures. In 1920 production from four wells from 550 to 600 ft. deep was about 20 bbl. per day.

San Juan Field.—The majority of drilling in this area was done during the years 1908 to 1911. Probably the first commercial well in the field was that drilled in NW.¼ sec. 6, T.42S, R.19E., in 1909.

Farnham Dome.—The discovery well was drilled by the Utah Oil Refining Co. in April, 1923. A number of years later a second well was drilled by The Carbon Dioxice and Chemical Co., the present operator, which markets the gas in the manufacture of "dry ice" and allied products. The estimated production, as indicated in Table 1, includes 500 million cubic feet estimated to have been lost while drilling the discovery well.

Cisco Dome.—The discovery well was drilled by The Utah Oil Refining Co. in November, 1924. The Crystal Carbon Co. markets the gas in the manufacture of carbon black.

Ashley Valley Dome.—The discovery well was drilled by the Utah Oil Refining Co. in April, 1925. The Uintah Gas Co. markets the gas in Vernal, Utah, for fuel.

Woodside Structure.—In February, 1924, gas was discovered in a well drilled by Utah Oil Refining Co. in sec. 12, T.19S., R.13E., on the Woodside structure. This gas is reported to contain an appreciable amount of helium. It is being held as a helium reserve by the United States Government.

Salt Valley Structure.—The test of the Utah Southern Oil Co. in sec. 31, T.23S., R.21E., on the Salt Valley structure has been shut down for some time at 6120 ft. This test has passed through more than 5000 ft.

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* Consulting Geologist.

TABLE 1.—*Oil and Gas Production in Utah*

eNumber	Field, *County*	Age, Years to End of 1933	Area Proved, Acres: Oil	Area Proved, Acres: Gas	Total Oil Production, Bbl.: To End of 1933	Total Oil Production, Bbl.: During 1932	Total Oil Production, Bbl.: During 1933	Total Oil Production, Bbl.: Daily Average during Nov., 1933	Total Gas Production, Millions Cu. Ft.: To End of 1933	Total Gas Production, Millions Cu. Ft.: During 1932	Total Gas Production, Millions Cu. Ft.: During 1933	Total Gas Production, Millions Cu. Ft.: Maximum Daily during 1933
1	Virgin, *Washington*	26	*y*		175,*xxx*	11,*xxx*	9,*xxx*	*y*				
2	San Juan, *San Juan*	24	*x*		10,*xxx*	6*xx*	250	*y*				
3	Farnham, *Carbon*	10		*x*					582	24	23	*y*
4	Cisco, *Grand*	9		*y*					3,119	0	0	0
5	Ashley Valley, *Uintah*	8		*y*					210	53	44	*y*
6	Total		*y*	*y*	185,000	11,6*xx*	9,*xxx*	*y*	3,911	77	67	

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Pressure, Lb. per Sq. In.[e]: Initial	Pressure: Average at End of 1932	Pressure: Average at End of 1933	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F.: Maximum	Gravity: Minimum	Sulfur, Per Cent	Base[f]
1	118	*y*	*y*	*y*	*y*		*y*	550	*y*				30	25	*y*	M
2	*y*	*y*	*y*	*y*	*y*		*y*	250	*y*				40	39	*y*	M
3	2	0	0	0	0	2	2	3,114	*y*	750	*y*	710				
4	*y*	0	0	9	0	9	9	2,100	1,950	750	*y*	300				
5	*y*	0	0	0	0	2	2	1,685	*y*	580	*y*	320				
6	*y*	*y*	*y*	*y*	*y*	13	*y*									

[e] Footnotes to column headings and explanation of symbols are on page 175.

Line Number	Character of Gas, Approx. Average during 1933: B.t.u. per Cu. Ft.	Gal. Gaso. per M. Cu. Ft.	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1			Virgin SS	Tri	LS	*y*	*y*	MU		Permian	*y*
2				Pen	LS	*y*	*y*	S		Pennsylvanian	*y*
3	*y*	*y*	?	Tri	*y*	*y*	*y*	A		*y*	3,114
4	*y*	*y*	Dakota	Cre L	S, S	*y*	*y*	A	*y*	La Plata SS	3,045
5	*y*	*y*	Dakota, Morrison	Cre L, Jur		*y*	*y*	A		Jurassic	*y*
6											

TABLE 2.—*Summary of Drilling Operations in Utah*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934[1]							
	Dry and/or Near-dry Holes							Productive Wells (For Details, see Table 1)
	Total Depths, Ft.							
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	Total	
Carbon	0	0	0	2	0	0	2	2
Duchesne	0	0	1	0	0	0	1	
Emery	0	0	5	0	1	0	6	
Garfield	0	0	1	0	0	0	1	
Grand	0	5	14	3	1	4	27	9
Kane	0	0	0	1	0	0	1	
San Juan	96	0	1	2	3	3	105	x
Summit	0	0	0	1	0	0	1	
Uintah	0	3	1	1	0	0	5	2
Utah	0	1	0	0	0	0	1	
Washington	118	0	1	2	0	0	121	x
Wayne	0	0	1	0	0	0	1	
Sevier							0	
Total	214	9	25	12	5	7	272	

[1] No wells completed during 1933.

of salt without reaching the lower limit. Some of this salt is reported to contain some small amounts of potassium salts.

Ramsay Test.—The test of the Ramsey Petroleum Co. in sec. 18, T.26S., R.7E., is drilling by lost tools at 270 feet.

Gas Analyses

Following are analyses of gas from the fields as indicated:

	Farnham, Per Cent	Cisco, Per Cent	Ashley Valley, Per Cent
Carbon dioxide	98.30	2.3	0.2
Oxygen	0.00	0.0	0.13
Methane	0.30	93.7	99.42
Nitrogen	1.14	0.2	0.24
Helium	0.03	0.0	0.01
Hydrogen sulfide	0.23		
Ethane and higher		3.8	
	100.00	100.0	100.00

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Oil and Gas Production in Wyoming

By John G. Bartram,* Casper, Wyoming

Table 1

Line Number	Field, *County*	Age, Years to End of 1933	Area Proved, Acres			
			Oil	Oil and Gas[a]	Gas	Total
1	Badger Basin, *Park*	3	?			?
	Baxter, *Sweetwater:*					
2	Frontier	11			4,500	
3	Dakota				6,000	
4	Total					
	Big Muddy, *Converse:*					
5	Wall Creek	17				
6	Dakota	11				
7	Total	17	2,600			2,600
8	Big Sand Draw, *Fremont*	16			500	500
9	Billy Creek, *Johnson*	12			700	700
10	Boone, *Natrona*	13			300	300
	Dallas, *Fremont:*					
11	Embar					
12	Tensleep					
13	Total	19	350			350
	East Byron, *Bighorn:*					
14	Frontier					?
15	Tensleep	1	?			?
16	Total					
	East Mahoney, *Carbon:*					
17	Dakota				3,100	3,100
18	Sundance				3,400	3,400
19	Total					
20	Eight Mile Lake, *Carbon*	10			250	250
	Elk Basin, *Park:*					
21	Frontier	18	580			580
22	Dakota	12			1,200	1,200
23	Total					
24	Ferris, *Carbon*	15	500			
	Frannie, *Park:*					
25	Tensleep					
26	Madison					
27	Total	5	300			300
	Garland, *Bighorn:*					
28	Frontier	26				
29	Dakota					
30	Embar-Tensleep	6			1,650	1,650
31	Madison		960			960
32	Total					
33	Hamilton, *Hot Springs*	15	640			640
34	Hidden Dome, *Washakie*	16			600	600
35	Labarge, *Lincoln, Sublette*	10	850	100		950
	Lance Creek, *Niobrara:*					
36	Dakota	11				1,500
37	Sundance	3				
38	Total					
	Lander, *Fremont:*					
39	Embar					
40	Tensleep					
41	Total	15	800			800
42	Little Buffalo Basin, *Hot Springs and Park*	19			4,800	4,800
43	Little Grass Creek, *Hot Springs*	17			160	160
44	Little Polecat, *Park*				500	500
	Lost Soldier, *Sweetwater:*					
45	Frontier					
46	Dakota					
47	Lakota					
48	Sundance					
49	Tensleep					
50	Total	17	350			350
	Mahoney, *Carbon:*					
51	Dakota				1,400	1,400
52	Sundance				1,660	1,660
53	Total					

* Stanolind Oil and Gas Co.

[a] Footnotes to column heads and explanation of symbols are on p. 175.

TABLE 1.—(*Continued*)

Line Number	Field, County	Age, Years to End of 1933	Area Proved, Acres: Oil	Oil and Gas[a]	Gas	Total
54	Midway, *Natrona*	3	200			200
55	Mule Creek, *Niobrara*	13	220			220
56	Muskrat, *Fremont*	6			500	500
57	North Baxter, *Sweetwater*	7			1,000	1,000
58	North Byron, *Park*	18			800	800
59	Notches, *Natrona*	11	400			400
	Oregon Basin, *Park:*					
60	Dakota	21			1,300	1,300
61	Embar-Tensleep	7	10,000			10,000
62	Total					
63	Pilot Butte, *Fremont*	17	250			250
64	Poison Spider, *Natrona*	15	1,100			
65	Rex Lake, *Albany*		200			200
66	Rock Creek, *Carbon*	16	1,300			1,300
	Salt Creek, *Natrona:*					
67	Upper Shale		8,855			
68	1st Wall Creek		4,351			
69	2d Wall Creek		21,450			
70	3d Wall Creek		1,280			
71	Lakota Shale		1,825			
72	Lakota		2,032			
73	2d Sundance		660			
74	3d Sundance		580			
75	Morrison		320			
76	Tensleep		640			
77	Total	25				
78	Spring Valley, *Uinta*		400			400
79	Teapot Dome, *Natrona*	11				2,400
80	Warm Springs, *Hot Springs*	16	150			150
	Wertz, *Carbon:*					
81	Frontier				100	
82	Dakota				500	
83	Lakota				500	
84	Sundance				200	
85	Total	13				500
	Grass Creek, *Hot Springs:*					
86	Frontier	19	1,400			1,400
87	Embar-Tensleep	12	900			900
88	Total					

[a] Footnotes to column heads and explanation of symbols are on p. 175.

Line Number	Total Oil Production, Bbl.: To End of 1933	During 1933	Daily Average during Nov. 1933	Average Oil Production in Barrels: Per Well Daily during Nov. 1933	Total Gas Production, Millions Cu. Ft.: To End of 1933	During 1932	During 1933
1	45,700	16,700	50	50			
2							
3					est 7,000	1,650	est 2,000
4							
5							
6							
7	23,055,000	647,000			34,000	2,500	2,250
8					1,100	235	220
9					3,900	75	80
10							
11							
12							
13	1,658,000	151,000		42	2,200	121	est 100
14							
15	60,000	9,000					
16							

TABLE 1.—(*Continued*)

Line Number	Total Oil Production, Bbl.			Average Oil Production in Barrels	Total Gas Production, Millions Cu. Ft		
	To End of 1933	During 1933	Daily Average during Nov. 1933	Per Well Daily during Nov. 1933	To End of 1933	During 1932	During 1933
17							
18							
19					22,800	355	175
20					4,700	None	est 100
21	10,049,000	212,000					
22					16,250	1,400	1,600
23							
24	461,800	6,950					
25							
26							
27	738,000	86,500					
28							
29							
30							
31							
32	833,000	172,700			est 20,600	150	est 150
33	3,034,000	220,000					
34					24,350	170	?
35	3,411,000	542,000					
36	4,214,000	27,500			est 56,000	est 3,500	est 2,500
37							
38							
39							
40							
41	1,426,000	119,000					
42					11,400	980	715
43					970	110	125
44					est 300	105	est. 100
45							
46							
47							
48							
49							
50	16,440,000	608,000					
51							
52							
53					52,300	2,230	440
54	94,000	37,500					
55	1,185,000	400					
56					1,950	670	640
57					2,120	990	est 1,000
58					5	3	2
59	170,000	None					
60					est 1,000	135	est 125
61	4,305,000	155,000					
62							
63	503,200	9,500					
64	2,390,000	161,000			16,900	None	None
65	205,000	2,600					
66	14,900,000	460,000					
67							
68							
69							
70							
71							
72							
73							
74							
75							
76							
77	252,050,000	7,150,000					
78	49,400						
79	3,670,000	7,600					
80	216,150	None					
81						None	
82						710	
83						3,010	
84						400	
85		3,100				4,120	
86	22,440,000	53,900					
87	1,284,000	218,000					
88							

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[c]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1933, Number of Wells: Flowing	Oil Production Methods at End of 1933, Number of Wells: Pumping	Pressure, Lb. per Sq. In.[e]: Initial	Pressure, Lb. per Sq. In.[e]: Average at End of 1932
1	1	0	0	1	1			1	8,500	8,250		1		
2									2,100	2,000			800	
3									2,600	2,500			775	
4	15	2					15	15						
5									3,400	3,260				
6								5	4,400	4,300				
7	156	2	0	0	156			156						
8	10	0	0	0			10	10	3,000	2,300			1,100–1,300	
9	8	0	0	0			8	8	3,250	3,200			1,150	
10	4	0	0	0					2,200	2,150				
11														
12														
13	42	0	0	0	42			42	1,200	700		42		
14	2	0	0	0			2	2	2,500	2,400			est 1,000	
15	1	0	0	0	1				5,400	5,300		1		
16														
17								2	2,300	2,200			700	
18	11							11	2,700	2,600			1,140	
19													1,600	
20	4							1	3,500	3,400				
21	144							144	1,200	1,000		144	925	
22	4	0	0	1			4	4	2,500	2,400				
23														
24	12							12		1,600		12		
25	7	1	0	0	7			7	2,900	2,800		7		
26	1				1			1	3,010	3,000	1			
27	8							8	2,900	2,800		18		
28									900	700				
29									1,600	1,500				
30							2	2	3,200	3,000				
31	3	0	0			3		3	4,400	4,000	3			
32														
33	28	0	0	0	28			28	2,600	2,300		28		
34	5								1,600	1,200			490	
35	97							97	1,000	650			1,176	
36					20				3,200	2,900				
37					2				3,700	3,650				
38														
39														
40														
41	35	0	0	0				35	1,800	1,200			445	405
42	10			2			8	8	1,500	1,200			850	
43	2							2	2,700	2,650			1,425	
44	1								4,100	3,900				
45									600	300				
46									1,600	1,500				
47									1,700	1,600				
48									2,000	1,900				
49									4,000	3,900				
50	75							75	2,300	2,200			825	
51									2,700	2,600			1,170	
52														
53														
54	2							2	5,300	5,200				
55	42	0	0	0	42			42	1,550	1,500			1,450	
56	1	0	0	0			1	1	4,400	4,350			825–1,475	
57	5							5	2,500–3,100	2,400–3,000				
58	4								2,400	2,200			400	
59	3	0	0	0	3			3	2,850	2,800			700	
60	2						2	2	1,600	1,500				
61	28							28	3,900	3,500				
62														
63	10								1,000	800				
64	26	0	0	0	26				2,700	2,600				

TABLE 1.—(*Continued*)

Line Number	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[c]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Average Depth, Ft.: Bottoms of Productive Wells	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1933, Number of Wells: Flowing	Oil Production Methods at End of 1933, Number of Wells: Pumping	Pressure, Lb. per Sq. In.: Initial	Pressure, Lb. per Sq. In.: Average at End of 1932
65	4	0	0	2	0			2	3,900	3,800				
66	65	0	0		65				2,800	2,600				
67	81								1,850	1,750				
68	317													
69	1,607								2,250	2,150				
70	12													
71	23								2,350	2,300				
72	90													
73 } 74	45								2,850	2,800				
75	2													
76	1								3,950	3,850				
77	2,178													
78	8													
79	89							2						
80	29								800	700				
81													850	exhausted
82							3		3,600	3,500			1,800	500
83							2		3,750	3,800			1,350	675
84							1		4,100	4,200			1,520	1,410
85	6	0	0					6	3,700	3,600				
86	328								1,200	800		328		
87	12								4,000	3,600		12		
88														

Line Number	Character of Oil, Approx. Average during 1933, Gravity A.P.I. at 60° F.: Maximum	Minimum	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
1	44		Frontier	Cre U	S	Por		D		Second Wall Creek	8,725
2			Frontier	Cre U	S	Por		AF		Jurassic	4,050
3			Dakota	Cre U	S	Por		AF		Jurassic	
4											
5	33		Wall Creek, Frontier	Cre U	S	Por		D		Sundance	4,763
6			Dakota-Lakota	Cre L-U	S	Por		D		Sundance	
7											
8			Frontier	Cre U	S	Por		D		Sundance	5,345
9			Frontier	Cre U	S	Por		D		Muddy sand	4,400
10			Shannon	Cre U	S	Por		D		Niobrara shale	5,200
11			Embar	Per	L	Cav-Por		D			
12			Tensleep	Pen	S	Por		D		Tensleep	1,400
13	21										
14			Frontier	Cre U	S	Por		AF		Tensleep	5,400
15	25		Tensleep	Pen	S	Por		AF		Tensleep	5,400
16											
17			Dakota	Cre U	S	Por		D		Tensleep	4,700
18			Sundance	Jur	S	Por		D		Tensleep	
19											
20			Dakota	Cre U	S	Por		D		Chugwater	4,561
21	43		Frontier	Cre U	S	Por		AF		Dakota	2,500
22			Dakota	Cre U	S	Por		AF		Dakota	2,500
23											
24	36		Mowry	Cre U	H	Fis		D		Tensleep	4,600
25	28		Tensleep	Pen	S	Por		AF		Madison	3,013

TABLE 1.—(*Continued*)

Line Number	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F. Maximum	Minimum	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole, Ft.
26	18		Madison	Mis	L	Fis		AF		Madison	3,013
27											
28	42		Frontier	Cre U	S	Por		AF		Madison	4,424
29			Dakota	Cre U	S	Por		AF		Madison	4,424
30			Embar-Tensleep	Per-Pen	L-S	Cav-Por		AF		Madison	4,424
31	19		Madison	Mis	L	Cav		AF		Madison	4,424
32										Madison	4,424
33	26	18	Embar-Tensleep	Per-Pen	L-S	Por		D		Tensleep	2,700
34			Frontier	Cre U	S	Por		D		Morrison	2,800
35	50	18	Wasatch	Eoc	S	Por		A		Hilliard shale	4,600
36	42		Dakota-Lakota								
37			Sundance								
38											
39			Embar								
40			Tensleep								
41	23										
42			Frontier	Cre U	S	Por	100	D	4	Thermopolis shale	1,700
43			Frontier								
44			Frontier								
45	32		Frontier								
46	33		Dakota								
47	30		Lakota								
48			Sundance								
49	35		Tensleep								
50											
51			Dakota								
52			Sundance								
53											
54	31		Second Wall Creek								
55	30		Lakota								
56			Frontier								
57			Frontier, Dakota								
58			Frontier								
59	22		Tensleep								
60			Dakota								
61	22	20	Embar-Tensleep								
62											
63	36		Niobrara shale								
64	22	15	Sundance, Tensleep								
65	33		Muddy-Dakota								
66	36		Muddy-Dakota								
67	35.5										
68	36		1st Wall Creek								
69	37		2d Wall Creek								
70	36										
71	35.5		Lakota								
72	34										
73	34		Sundance								
74	35										
75	30										
76	28		Tensleep								
77										Granite	5,400
78	38		Aspen shale	Cre U	H	Fis		MC			
79	35		Frontier	Cre U	S			AF		3d Wall Creek	
80	21		Embar	Per	L	Por		D		Tensleep sand	
81			Frontier	Cre U	S	Por	50	D			
82			Dakota	Cre U	S	Por	50	D			
83			Lakota	Cre L	S	Por	40	D			
84			Sundance	Jur	S	Por	110	D		Sundance	
85									3	Sundance	4,200
86	43		Frontier	Cre U	S	Por		D			
87	25		Embar-Tensleep	Per-Pen	L-S	Por		D		Amsden	
88											

TABLE 2.—*Summary of Drilling Operations in Wyoming*

(Figures in body of tabulation represent number of holes.)

County	Completed during 1933						Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes					Productive Wells (For Details See Table 1)		
	Total Depths, Ft.							
	Less than 1000	1000–2000	2000–3000	3000–4000	Total		Within Fields	Exploratory
Albany		1			1			
Big Horn	2	1			3	1	1	
Campbell								
Carbon	1				1	4	1	2
Converse		1			1			
Crook	1	1			2			3
Fremont		1			1	2		
Goshen								
Hot Springs	1				1		1	
Johnson								
Laramie								
Lincoln		1			1			
Natrona	4	1	2		7	2	1	
Niobrara								2
Park						3		1
Platte	1				1			
Sheridan								1
Sublette	1		1		2			2
Sheetwater			1		1	5		
Uinta	3	2	1		6			1
Washakie		1			1		3	
Weston	2	2	2	1	7	21	3	
Total	16	12	7	1	36	38	10	12

Oil and Gas Development in the Argentine Republic

By Guillermo Hileman,* Buenos Aires, Argentine Republic

(New York Meeting, February, 1934)

At present there are three fields in commercial exploitation in the Argentine. In order of production they are: (1) Comodoro Rivadavia, (2) Salta, (3) Plaza Huincul.

Comodoro Rivadavia.—This field is on the coast of the Territory of Chubut in the southern part of the republic. It is being developed and exploited by Yacimientos Petrolíferos Fiscales, the government oil entity, and five private companies. The immediate coastal portion of the field, which embraces the original discovery area, is almost completely developed. This is especially true of the original government reserve and one private property. The Y.P.F. has extended its explorations and developments westward to Escalante, 27 km. distant on the state railway. This extension has been the most active and prolific section of the field for the past three years. The government has also continued its exploration drilling in the region lying south of Colonia Sarmiento and east of the Río Senguer. Private companies have not been able to extend their operations beyond the claims they had in process of acquisition in 1924, when the government reserve areas were established.

The Y.P.F. is the major producer of the field and employs modern methods and appliances. Practically all its drilling and pumping operations are electrically operated, from a central power plant. In view of the scarcity of water supplies, this facilitates operations and is an economic factor of considerable importance.

Table 1.—*Oil and Gas Production in the Republic of Argentine*

Line Number	Field	Age, Years, to End of 1933	Area Proved, Acres			Total Oil Production, Bbl.			
			Oil	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Comodoro Rivadavia, Territory of Chubut	26	20,000	4,900	24,900	95,530,577	10,281,941	10,307,992	28,367
2	Plaza Huincul, Territory of Neuquén	15	4,000	2,400	6,400	9,063,461	1,811,438	1,432,640	3,644
3	Salta, Province of Salta	8				4,172,570	1,019,464	1,909,241	5,110
4	Cacheuta, Province of Mendoza	2				10,152	1,586	8,566	
5	El Sosneado, Province of Mendoza	8				145,932	34,258	45,770	

* Bureau of Mines, Argentine Republic.

The characteristics of the field are ideal for using rotary drilling equipment, therefore, except in deep exploration tests, wells are completed in a relatively short time. In addition, the experience and knowledge gained from the long period of exploitation enable operators to use the smallest possible amount of casing. In a few zones, water shutoff is made with one string of casing in which the tubing is set.

Salta.—The Province of Salta is in the northwestern part of the Argentine, bordering Bolivia. The semitropical climate and heavy vegetation obtaining in this region offer difficulties for every type of operation from geological exploration to production. The rugged nature of the topography requires expensive road construction for the transportation of drilling equipment and supplies. Also, the prevailing type of structure usually has very sharply inclined flanks causing well locations, drilling and production operations to be much more costly than on average terrain.

The production in this zone has increased steadily since the first commercial exploitation began in 1926. It is largely on account of the 87 per cent increase in 1933 production from the Salta fields that the total production of the republic increased over that of 1932. The Y.P.F. and one private company are the sole producers, although a second private concern began exploration drilling in the province during this year. The crude is of high quality and most of the residue from topping is utilized for the production of lubricating oils.

Plaza Huincul.—This field is in the south central part of the republic in the Territory of Neuquén which adjoins the Republic of Chile. The geological phases of the field are complicated while the pools are rather concentrated or of limited extent. Drilling operations are not difficult. The various strata stand up well, reducing casing strings to a minimum and favoring the use of cable tools. Considering the extensive prospective areas included in this territory and the lack of exploration work, especially drilling, optimism for its future still prevails. At the

TABLE 1.—(*Continued*)

Line Number	Average Oil Production, Bbl.		Total Gas Production, Millions Cu. Ft.				Number of Oil and/or Gas Wells						
								During 1933		At End of 1933			
	Per Acre to of 1933[b]	Per Well Daily during Nov., 1933	To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Completed to End of 1933	Completed	Abandoned	Temporarily Shut Down	Producing Oil Only	Producing Gas Only	Total Producing
1	4,777	15	114,416	15,881	19,012	63	2,868	225	59	428	1,828	49	1,877
2	2,266	13	7,996	2,546	2,349	7.6	418	48	6	21	271	5	276
3		44		964[1]	1,747[1]	4.7	153	30		37	116		116
4							6	3	2		4		4
5							6				6		6

[b] Footnotes to column headings and explanation of symbols are on page 175.
[1] Total amount treated in gas plants.

close of 1933 the Yacimientos Petrolíferos Fiscales and two private companies were the sole operators in this field.

Mention should be made of the two small fields in the Province of Mendoza. Up to the present, they have produced very little although there was a small increase in 1933. The oil from the southern field is noteworthy because of the asphalt and lubricating-oil content. Production from Mendoza is as yet of little commercial importance, because of the limited amount and the distances from commercial centers and rail transport.

Geological, geophysical and exploration drilling activities in the Argentine probably were carried out on a larger scale during 1933 than at any period since 1924 or 1925. This can be attributed to the more comprehensive exploration program of the Y.P.F. in search of new production. In substantiation of this statement, it is only necessary to mention their drilling operations in the following points: west of Comodoro Rivadavia; the areas both east and west of the Plaza Huincul field; Territory of Río Negro in the vicinity of Bariloche; the north and south central parts of the Province of Mendoza; Department of San Crístobal in the Province of Santa Fé; Río Pescado and Campo Durán in the

TABLE 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1933						Character of Oil, Approx. Average during 1933				
			Number of Wells					Injection into Reservoir[d]	Gravity A.P.I. at 60°F.			Sulfur, Per Cent	Base[f]
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.		Maximum	Minimum	Weighted Average		
1	1,755	1,745	12	1,696	100	4	47		32	17	21	018	P A
2	2,501	2,411	14	238	5		4		40	30	34		P
3									50	44	45		P
4							4						A
5						6					12	1.4	A

Line Number	Character of Gas Approx. Average during 1933		Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933	
	B.t.u. per Cu. Ft.	Gal. Gasoline Per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average, Ft.			Name	Depth of Hole, Ft.
1	849	0.10 to 0.52	Chubutiano and Glauconitico	Cre	SS	Por	39	AF	290	Lower Chubutiano; Possibly Cre-L	6,617
2	877	1.50	Dogger	Jur-U	S	Por	90	MU Af	106	Liassic	4,826
3			Clay Grit Series	Per-Tri	SS	Por		A	29y		
4			Red Beds	Cre-U	SS	Por		A	3y		
5			Ranch House Conglomerate	Tert	SS			Mlf	4y		

Province of Salta and one test in the Province of Jujuy. The success of this extensive program awaits the results of these wells.

Practically the entire crude production of the country is refined and elaborated by the topping, cracking and refining plants now existing in the country. Presently, their capacity will be sufficient to supply all the petroleum products required by the domestic market since the additional crude requirements are supplied by importation. At present, the

TABLE 2.—*Summary of Drilling Operations in Republic of Argentine*
(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934									Completed during 1933								Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes								Productive Wells	Dry and/or Near-dry Holes							Productive Wells		
	Total Depths, Ft.							Total	(For Details, See Table 1)	Total Depths, Ft.						Total	(For Details See Table 1)	Within Fields	Exploratory
	500–1,000	1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000			1,000–2,000	2,000–3,000	3,000–4,000	4,000–5,000	5,000–6,000	6,000–7,000				
Territory of Chubut			277	11		1	1	290	2868		53	5			1	59	225	40	7
Territory of Neuquén		6	5	90	2	3		106	418			5	1			6	48	10	4
Territory of Río Negro	3							3											2
Province of Jujuy			5	2	1			8											1
Province of Salta		2	18	7		2		29			2	2	2				6	13	5
Province of Santa Fe																			1
Province of Mendoza		3	1	1				5	10	1						1	3		3
Total								441	3296							66	282	63	23

importation of crude oil, fuel oil, gasoline, lubricating oils and asphalt is slowly declining from year to year, owing both to the increase of local production and to the increased local manufacture of refined products. A more recent factor affecting importations is the decline in consumption.

The topping, cracking and refining plants are at strategic points in the republic as follows: Bahía Blanca, Buenos Aires, Campana, Comodoro Rivadavia, Plaza Huincul and Manuel Elordí and Vespucio in the Province of Salta.

In 1932 the Senate passed a proposed petroleum law but the bill failed to reach the House of Deputies in either the regular or the called session of Congress. Just prior to the close of the regular sessions of Congress in 1933, the proposed bill as revised by the House Committees was approved by the House of Deputies as to form but failed of final passage. It is presumed that the bill will come up for consideration in the regular sessions of Congress during the present year. The project proposes to provide concessions both for Yacimientos Petrolíferos Fiscales and private capital.

If approved the new law should fill a necessity of long standing and contribute to the development of new activities in the search for additional sources of crude, since the present crude production does not supply the consumption. Also, recent geological investigations in different zones have disclosed conditions sufficiently favorable to justify exploration drilling.

Only recently the Federal Government by decree approved a set of regulations governing operations in all fields of the republic.

Petroleum Production and Development in Austria, Hungary and Czechoslovakia in 1933

By Walter M. Small,* Vienna, Austria

(New York Meeting, February, 1934)

Austria

From the one producing well in Austria, 7000 bbl. of heavy oil was produced and sold in 1933. This well, owned by the Raky-Danubia, was completed late in 1932 in the formation called Flysch (Upper Cretaceous or lower Eocene) near Zistersdorf north of Vienna. Two wildcats drilling in the vicinity have not yet reached the producing beds.

Near Vienna, the European Gas and Electric Co. drilled five shallow wells for gas, three of which were failures. One gas well was completed for 8 million cu. ft. capacity at 260 meters depth and with a pressure of 570 lb. Another is being tested following blowouts. One gas well and one dry hole were completed in the pool in 1932.

In Upper Austria, the same company abandoned one wildcat at 679 m. and is drilling at 280 m. on a second.

No gas was sold during the year, but a line is being completed to supply fuel to boilers of the Vienna Electric Works.

Hungary

No deep drilling was done in 1933. Oil and gas concession was granted by Parliament to the European Gas and Electric Co. on Transdanubia. Active geological and geophysical investigation is in progress.

Czechoslovakia

In the Gbely and Hodonin shallow fields, some 26 wells were drilled of which three were reported as failures. The total production of the fields was 111,736 bbl. of oil and 40 million cu. ft. of gas used as fuel in the field.

At Vacenovice, where there were already two small gas wells, a third producer was completed at 420 m. This pool markets a small amount of gas, which is compressed and used to light railway carriages.

Wildcat wells were reported drilling at about 300 m. depth at both Jasina and Telnice. One 700-m. wildcat near the Hodonin field was abandoned. Another failure was reported completed and abandoned at 820 m. near Holic.

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* European Gas & Electric Co.

In the oil fields Gbely and Hodonin 426 wells have been drilled, ranging in depth from 140 to 540 m. The production for the year is shown on the attached table. Total drilling to date has been 124,000 m. About 30 per cent of the wells have been failures. The shallowest producer is 117 m., and the deepest is 542 m. The shallow Sarmat (Uppermost Miocene) oil in these fields has a gravity of 18° A.P.I., while the Torton (Miocene just below the Sarmat) oil has a gravity of 23° A.P.I. Some deeper Torton oil has a gravity of 40° A.P.I. The wells are drilled with the Fauck-Schenk system or the Trauzlwerke machines, a water-flush method with percussion stroke, the returns coming out through the drill rods.

Production in Gbely and Hodonin Oil Fields

Year	Gbely, Bbl.	Hodonin, Bbl.
1914	11,003	
1915	31,523	
1916	32,738	
1917	59,873	
1918	64,733	
1919	47,250	
1920	69,930	68
1921	93,623	945
1922	119,813	3,780
1923	72,090	878
1924	48,668	26,595
1925	49,545	107,933
1926	56,700	92,475
1927	35,775	75,465
1928	42,863	51,165
1929	59,265	34,088
1930	84,173	69,925
1931	37,665	54,945
1932	77,625	46,980
1933	74,250	45,360

Petroleum Development at Bahrein Island (Arabia)

By G. C. Gester,* San Francisco, Calif.

(New York Meeting, February, 1934)

Oil has been produced in Persia and India for many years, but it was not until 1932 that Arabia entered the arena as a potential oil-producing area. In 1930 the Standard Oil Co. of California acquired a concession covering the rights of exploration and exploitation for oil in the Bahrein Islands and in June, 1932, the first commercial production was discovered by the bringing in of a well known as Jebel Dukhan No. 1 on the Island of Bahrein. Since then the Standard Oil Co. of California through its wholly owned subsidiary, The Bahrein Petroleum Co. Ltd., has been carrying on a systematic survey and development program of its concession in the Bahrein Islands.

This group of islands, of which Bahrein is the largest, is in the southwestern portion of the Persian Gulf, approximately 25 miles from the mainland of Arabia. Although geographically a part of Arabia, the islands are not a part of the Kingdom of Saudi Arabia. Their government is essentially independent but certain special rights have been granted to Great Britain through a series of treaties.

The Island of Bahrein is 32 miles long by 9½ miles wide and covers an area of 215 square miles. Approximately three-fourths of the island is occupied by a relatively low, broad, elliptically shaped dissected hill, the central part of which is slightly depressed with inward-facing cliffs but culminating in the Jebel Dukhan (Hill of Smoke), which rises to an elevation of 443 ft. above sea level. The topography of the island is a good index of its geologic structure.

Structurally the island is an elongated dome or quaquaversal fold composed of rocks of Eocene age. The major axis of the fold strikes N.5W. All of the topographic high portion of the island is a part of the structural uplift. The crest of the fold is broad and flat with the dips increasing on the flanks. How far tilted strata may continue beyond the line where the Eocene beds are covered by recent sands and detrital material is not known. Superimposed on the general structure are a few small irregularities in the form of minor folding and faulting. There is, however, no evidence of any major faults. The largest of the irregularities lies to the south of Jebel Dukhan and has the appearance of a sink

* Standard Oil Co. of California.

which has diverted the main surface axis somewhat to the westward. Except for the shore sands and recent alluvium, the rock formation of the island consists of a series of limestones, sands and marls, which have an exposed thickness of about 300 ft. Some of the beds are fossiliferous, carrying a well preserved fauna, which is correlative in age with the Eocene of Persia. In general, the colors of the exposed rocks are drab, varying from dull white to gray through buff and yellow. They are for the most part well stratified and it was found that several different horizons could be used as marker beds for structural mapping. Near the central part of the island and about three miles southerly from the Jebel Dukhan, there is a relatively small deposit of bitumen. This occurs as a dry impregnated sand and limy material in beds representative of nearly the lowest exposed on the island.

The first well, Jebel Dukhan No. 1, was located near the center of the island at the southeasterly base of the little group of peaks that forms the Jebel Dukhan. Drilling was commenced on this well in October, 1931, and it was completed as a flowing well in June, 1932. The following is quoted from an article by G. C. Gester:[1]

> The formations encountered in drilling this well (Jebel Dukhan No. 1) were for the most part porous limestones with minor amounts of marl and calcareous sand. At a depth of about 1,400 feet the formation become somewhat shaly and at 1538 feet casing was landed in blue calcareous shale. From that depth to the bottom of the hole, at 2008 feet, there were more thinner bedded marly shales and impure porous limestones than in the upper part of the hole. Heavy oil and tar were encountered in the well just below 600 feet becoming lighter and more gassy with depth. The bottom eight or ten feet of the hole was so rich in oil and gas that there was danger of blowing out. The well was accordingly tested at that point and brought in as a flowing well, estimated as being capable of producing from 800 to 1400 bbls. daily with a shut-in pressure of 445 pounds. Gravity of the oil is 33.8° A.P.I.
>
> Well No. 2 is located slightly over two miles due north of No. 1 and at the same depth as No. 1 came in with a production of 1550 bbls. daily, 34° gravity oil. Well No. 3 was then located down the flank a distance of about 8000 feet northeasterly from No. 2. This was drilled to a depth of 2320 feet but water was encountered near the bottom of the hole. After plugging off the water this well was brought in at an estimated production of between 700 and 800 barrels daily with a shut-in pressure of 450 pounds.

Well No. 4 is on the west flank of the structure, approximately three miles southwesterly from well No. 1. At a depth of 2440 ft. this well penetrated porous limestone with strong showings of oil and gas. Casing was recently cemented at a depth of 2431 ft. but to date it has not been tested.

A derrick was erected at location No. 5 in the northern portion of the island but no drilling has been done on this well. Wells 6, 7 and 8, all on the higher parts of the structure, have recently started drilling.

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[1] *Oil & Gas Jnl.* (Dec. 28, 1933).

A well-spacing program designed to give as nearly as possible equal drainage areas per well has been worked out and is being put into effect. Blocks and sections were laid off on either side of a north-south base line which runs through the central part of the island. The sections are parallelograms with 9000-ft. sides formed by north-south lines which are cut by cross lines having bearings of N.60E. Twenty sections form a block. The blocks are lettered and the sections numbered. All numbering starts from the northwest corner. Each section contains 81 well locations on points of equilateral triangles, the sides of which are 1000 ft. This gives a well spacing of 19.88 acres per well. The well numbering system is unique in that each well number gives its location within a section. The well numbers commence with No. 11, which is the northwesternmost location in each section; the third location south on that line is 13; a location 3 easterly and 3 south is 33; 7 easterly and 5 southerly will be 75.

A permanent camp with the necessary machine shops, etc., is being built and water-supply system has been installed; and preparations are being made to construct a pipe line to the Island of Sitra, which is only a short distance from Bahrein Island on the eastern side, a few miles north of an east-west line through the central part of the island.

Oil and Gas Developments in Canada during 1933*

By G. S. Hume, Ottawa, Canada

(New York Meeting, February, 1934)

Three provinces in Canada—New Brunswick, Ontario and Alberta—produce oil and gas in commercial quantities. In addition a small amount of oil is being produced and refined in the Northwest Territories at Norman on the Mackenzie River. The production at Norman is derived from two wells drilled by Northwest (Imperial Oil) Co. in 1920 and 1923. The refined products of the oil are used locally in connection with mineral developments on Great Bear Lake. The production of petroleum by provinces and the consumption of natural gas are shown in Table 3. In addition a small amount of natural gas is produced in the southwestern part of Manitoba from shallow wells for local use. Tables 1 and 2 give detailed information.

Table 3.—*Production of Petroleum and Consumption of Natural Gas in Canada*

	Production of Petroleum, Bbl.			
	Alberta	Ontario	New Brunswick	N.W.T.
1931	1,413,631	122,365	6,577	
1932	906,751	130,343	6,408	910
1933	1,012,237	136,059	10,121	
	Consumption of Natural Gas, M. Cu. Ft.			
1931	17,798,698	7,419,534	655,891	
1932	15,985,744	7,244,624	645,010	
1933	16,860,000	7,163,895	618,000	

The greatest drilling activity in 1933 in Canada centered around the southern end of the Turner Valley field, Alberta. In addition to several wells previously commenced in this area, eleven new wells were begun. There were three completions to the Paleozoic producing zone in 1933 in the southern part of Turner Valley and one well was abandoned as a result of being off the favorable structure. Of two wells completed in

* Published with permission of the Director, Geological Survey of Canada, Department of Mines, Ottawa.

TABLE 1.—*Oil and Gas Production in Canada*

By G. S. Hume, Ottawa, Ontario in Cooperation with Wm. Calder, Dept. of Lands and Mines, Alta, Col. R. B. Harkness, Commissioner of Natural Gas, Ontario and Dr. J. A. L. Henderson, New Brunswick

Field	Province	Age in Years to End of 1933	Air Proved in Acres				Total Oil Production in Barrels				Average Oil Production in Barrels		
			Oil	Oil and Gas[a]	Gas	Total	To End of 1933	During 1932 35 Imperial Gallons in Barrels	During 1933	Daily Average during Nov. 1933	Per Acre to End of 1933[b]	Per Acre-Foot to End 1933	Per Well Daily during Nov. 1933
Turner Valley	Alberta (Foothills)	9					6,453,088	Naphtha 854,116	952,885	3,022	758		36.5
							407,947	Crude Oil 21,694	23,822	115	Faulting makes est. of area and av. thick. impossible		16.4
Red Coulee	Alberta (Plains)	4					184,880	34,315	30,254	60	2,310	115	12.0
Skiff	Alberta (Plains)	6½					5,914	Shut in			148		
Wainwright[m]	Alberta (Plains)	8					57,883	6,935	5,276	16.8			5.6
Viking	Alberta (Plains)	Discovered 1914 Opened up 1933, i.e. 10 yr.											
Fabyan[n]	Alberta (Plains)	9											
Foremost	Alberta (Plains)	18											
Medicine Hat[q]	Alberta (Plains)	25											
Brooks	Alberta (Plains)	Discovered 1910											
Range	Alberta (Plains)	Discovered 1925 Began prod. 1931, i.e. 3 yrs.											
Kinsella[p]	Alberta (Plains)	Discovered 1929 Not used yet											
Bow Island	Alberta (Plains)	Discovered 1908 Used 1912–28											
Barnwell	Alberta (Plains)	Discovered 1918					15,074	All wells abandoned			150		
Ribstone	Alberta (Plains)						803	nil	803	1.5			1.5
Keho	Alberta (Plains)						1,108	562	546	1 well abandoned			nil
Twin River	Alberta (Plains)									1 not completed			
Stony Creek	New Brunswick	2[1]	225		1,400	1,500	145,000	7,618	10,121		1,600		4.5
Petrolia and Enniskillen tp.	Ontario	69	8,000 ±				15,580,000	58,871	57,298				
Oil Springs	Ontario	73	750				7,664,750	31,438	31,343				
Moore tp.	Ontario	30	4,000				included in	3,272	2,192				
Sarnia tp.	Ontario	60	4,000				Enniskillen	1,227	2,181				
Plympton tp.	Ontario	60	2,800				and Petrolia	274	211				
Bothwell	Ontario	39	400				2,337,000	19,460	22,935				
Dover tp.	Ontario	17		300			82,750	453	763				
Dawn tp.	Ontario	37	100				50,000	5,061	8,589				
Onondaga tp.	Ontario	24	1,920				40,000	543	946				
Mosa tp.	Ontario	17	4,000				312,000	8,429	8,168				
Thamesville	Ontario	17	300				36,300	534	847				
Dunwich tp.	Ontario	36	500				178,300	781	347				
Tilbury E. tp.	Ontario	29	3,000	1,200			1,112,214		239				
Abandoned—Miscellaneous							355,000						

[a] Footnotes to column heads and explanation of symbols are on p. 175.
[1] Discovered June, 1909. Producing since 1911.

TABLE 1.—(*Continued*)

Field	Province	Total Gas Production in Millions of Cubic Feet: To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	Producing Oil Only	Producing Oil and Gas[e]	Producing Gas Only	Total Producing	Depth Average in Feet
Turner Valley	Alberta (Foothills)	604,000[z]	111,260	95,500	295[z]	96[2]	4	1	4		91		91	min. 3,740 max. 6,723
		Of these amounts the following were used.												
		88,500	10,892	11,200		8[3]	1	1		8			8	2,900 to 4,900
Red Coulee	Alberta (Plains)					7			2	5			5	min. 2,442 max. 2,507 3,050 to 3,080
Skiff	Alberta (Plains)					11	0		7	2		2	4	2,100 to 2,300
Wainwright[m]	Alberta (Plains)					23							23	2,100 to 2,225
Viking	Alberta (Plains)	23,771	2,895	2,979	21.8	4	1 repaired	0	1			3	3	1,770 to 1,870
Fabyan[n]	Alberta (Plains)	891	115	110	0.8	6	0	0	6					2,070 to 2,250
Foremost	Alberta (Plains)		67	1										1,000 to 1,300
Medicine Hat[q]	Alberta (Plains)	21,712	2,430	2,440[q]		5							5	1,240 to 1,540
Brooks	Alberta (Plains)	787	51	48			1							2,530 and 2,720
Range	Alberta (Plains)	185	38	82	0.3[z]									2,083 to 2,184
Kinsella[p]	Alberta (Plains)	nil	nil	nil[p]										
Bow Island	Alberta (Plains)	33,851	Exhausted 1928, repressured 1930–33							Use 7 wells for repressuring Use 3 for observation				1,900
Barnwell	Alberta (Plains)	1,445	nil	nil				4						
Ribstone	Alberta (Plains)						1						1	Oil at 3,800
Keho	Alberta (Plains)													
Twin River	Alberta (Plains)													
Stony Creek	New Brunswick	14,000	662.5	618		← 63	1	2	7 —1932—	15	1	31	47 →	1,500 to 3,200
Petrolia and Enniskillen tp	Ontario							119	773	817			1,590	470 to 510
Oil Springs	Ontario							21	275	804			1,079	370 to 400
Moore tp	Ontario							2	21	72			93	470 to 495
Sarnia tp	Ontario							5	47	70			117	470 to 485
Plympton tp	Ontario								5	26			31	450 to 525
Bothwell	Ontario							10	151	147			298	395 to 410
Dover tp	Ontario										2		2	3,100 to 3,300
Dawn tp	Ontario									2			2	320 to 370
Onondaga tp	Ontario								10				10	480 to 650
Mosa tp	Ontario								21	84			105	{275 to 325 / 375 to 425}
Thamesville	Ontario								24				24	370 to 380
Dunwich tp	Ontario								89	10			99	{330 to 350 / 400 to 400}
Tilbury E. tp	Ontario									2			2	1,300 to 1,400
Abandoned—Miscellaneous									123				123	

[2] Naphtha.
[3] Crude oil.

TABLE 1.—(*Continued*)

Field	Province	Oil Production Methods at End of 1933: Number of Wells: Flowing	Pumping or bailing	Gas-lift	Air-lift	Misc.	Injection into Reservoir[d]	Pressure, Lb. per Sq. In.[e]: Initial	Average at End of 1932	Average at End of 1933	Character of Oil Approx. Average during 1933: Gravity A.P.I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas Approx. Average during 1933: B.t.u. per Cu. Ft. as at 0° C. 760 m.m.	Gals. Gasoline per M. Cu. Ft.
Turner Valley	Alberta (Foothills)	91	8					?	1,790–680	1,690–535	85? weathers to 65 50	weathers 55 40	 63[z] 46[z]		 P P	stripped 1,055	aver. 0.29
Red Coulee	Alberta (Plains)		7								3		31 ±		M		
Skiff	Alberta (Plains)										20				M		
Wainwright[m]	Alberta (Plains)		2								23.6	17.6	19.8		A		
Viking	Alberta (Plains)							710	620	615						1,039	
Fabyan[n]	Alberta (Plains)																
Foremost	Alberta (Plains)							660	581 wells repaired	583							
Medicine Hat[q]	Alberta (Plains)							645	395	412							
Brooks	Alberta (Plains)									354–175							
Range	Alberta (Plains)								After excluding lower gas (H_2S) 1,030								
Kinsella[p]	Alberta (Plains)									754							
Bow Island	Alberta (Plains)							745	August 384 In 1927 241	August 426							
Barnwell	Alberta (Plains)																
Ribstone	Alberta (Plains)										15.3	11.9	14.5		A		
Keho	Alberta (Plains)		1										30		M		
Twin River	Alberta (Plains)		15										32		M		
Stony Creek	New Brunswick							Max. 1,100		195–200			37.3	0.08	P	1,130	0.8–1 pint
Petrolia and Enniskillen tp.	Ontario																
Oil Springs	Ontario																
Moore tp.	Ontario																
Sarnia tp.	Ontario																
Plympton tp.	Ontario																
Bothwell	Ontario																
Dover tp.	Ontario																
Dawn tp.	Ontario																
Onondaga tp.	Ontario												39				
Mosa tp.	Ontario																
Thamesville	Ontario																
Dunwich tp.	Ontario												42				
Tilbury E. tp.	Ontario										41		38				
Abandoned—Miscellaneous																	

TABLE 1.—(*Continued*)

Field	Province	Producing Rock: Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average, Ft.	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole in Ft.
Naphtha										
Turner Valley	Alberta	Rundle	Mis.	L	Por Cret fissures		AF	31	Deep wells pass through a low-angle fault from Miss. or (Dev.) into Cret.	7,751
	(Foothills)	Lower Cret. Jur.	Cret. Jur.	S	Por		AF			
Crude oil										
Red Coulee	Alberta (Plains)	Lower Cretaceous	Cre L.	S	Por		T			2,549
Skiff	Alberta (Plains)	Ellis	Jur.	S	Por		AM?		Mississippian	3,295
Wainwright[m]	Alberta (Plains)	Lower Cretaceous (Viking sand)	Cre L	S	Por		A		Devonian	2.698
Viking	Alberta (Plains)	Alberta shale (Viking sand)	Cret U	S	Por		A		Devonian	3,040
Fabyan[n]	Alberta (Plains)	Alberta shale (Bow Island Sand)	Cret U	S	Por		A		Devonian	2,730
Foremost	Alberta (Plains)	Alberta shale (Medicine Hat Sand)	Cret U	S	Por		A		Mississippian	3,716
Medicine Hat[q]	Alberta (Plains)	Alberta shale	Cret U	S	Por		A		Devonian	3,940
Brooks	Alberta (Plains)	Milk River and Upper Alberta shale	Cret U	S	Por		?		Lower Cretaceous?	2,795
Range	Alberta (Plains)	Sunburst sand Lower Cretaceous	Cret L	S	Por		MI?		Mississippian	2,918
Kinsella[p]	Alberta (Plains)	Viking sand	Cre U	S	Por		H?		Upper Cretaceous	2,184
Bow Island	Alberta (Plains)	Bow Island Sand	Cre U	S	Por		D		Devonian	4,060
Barnwell	Alberta (Plains)	Bow Island Sand	Cre U	S	Por		A?		Upper Cretaceous	2,617
Ribstone	Alberta (Plains)	Meridian sand	Cre L	S	Por		H?		Devonian	3,489
Keho	Alberta (Plains)	Keho-Bow Is.	Cre U	S	Por		?		Devonian	4,919
Twin River	Alberta (Plains)	Miss. lime	Mis.	L	Por	6,000	?		Mississippian	4,146
Stony Creek	New Brunswick	Albert	Mis.	S			AMF		A few wells have penetrated pre-Carboniferous igneous rocks (Pre-Cambrian?)	4,500
Petrolia and Enniskillen tp	Ontario	Onondaga	Dev	L		5 to 13	A		Trenton	3,947
Oil Springs	Ontario	Delaware	Dev	L		5 to 10	D		Trenton	3,750?
Moore tp	Ontario	Onondaga?	Dev	L			?		Trenton	4,420
Sarnia tp	Ontario	Delaware	Dev	L			D?		Salina	1,614
Plympton tp	Ontario	Onondaga	Dev	L			A		Silurian?	710
Bothwell	Ontario	Onondaga	Dev	L			A Faulted		Pre-Cambrian	3,998
Dover tp	Ontario	Trenton	Ord	L			S		Pre-Cambrian	4,003
Dawn tp	Ontario	Onondaga	Dev	L			D		Pre-Cambrian	3,968
Onondaga tp	Ontario	Whirlpool	Sil	S			?		Pre-Cambrian	2,712
Mosa tp	Ontario	Widder / Delaware	Dev / Dev	L / L			D		Pre-Cambrian	3,755
Thamesville	Ontario	Onondaga	Dev	L			A		Pre-Cambrian	3,981
Dunwich tp	Ontario	Onondaga	Dev	L			D		Pre-Cambrian	3,585
Tilbury E. tp	Ontario	Base of Salina or top of Guelph	Sil	L or D			D?		Pre-Cambrian	3,775
Abandoned—Miscellaneous										

TABLE 2.—*Gas Production in Ontario, Canada*

By G. S. Hume in Cooperation with Col. R. B. Harkness, Commissioner of Natural Gas, Ontario

Field	County	Age, Years to End of 1933	Area Proved in Acres	Total Gas Production in Millions of Cubic Feet			Number of Gas Wells							Average Depth, Ft.	
								During 1933		At End of 1932					
			Gas	To End of 1933	During 1932	During 1933	Estimate Completed to End of 1932	Completed	Abandoned	Temporarily Shut Down	Producing Oil and Gas[c]	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
S. W. Ontario............	Essex	45	2,000	22,000			30					24			
	Kent	28	15,000	167,210	4,506	4,453	500	5	2	1	2	328	331	1,400	1,200
	Lambton	19	1,000	1,375	171	263	70					39	39	1,600	1,400
	Middlesex	3	200				6			6			6	1,500	1,450
	Elgin	24	9,400	3,883	46	48	75		3			36	36	(1,270, 1,400)	(1,250, 1,380)
	Norfolk	11	18,900	7,555	366	336	300	2	2			144	144	(1,000, 1,200)	(870, 1,000)
	Haldimand	43	145,000				2,500	131	19			1,246	1,246	(400, 900)	(350, 870)
	Wentworth	40	6,000	58,520	1,454	1,537	150	4				65	65	(300, 390)	(428, 440)
	Lincoln	35	5,400				100	1				67	67	(315, 395)	(433, 500)
	Welland	44	38,000	39,723	352	333	500	6	11			272	272	(400, 775)	(430, 910)
	Brant	30	3,000	1,214	141	119	150	2	5			99	99	(360, 415)	(485, 532)
	Bruce	34	300	80			4			2			2		
	Peel		400				6			6			6		
	Miscellaneous					75									

[c] Footnotes to column heads and explanation of sym bols are on page 175.

TABLE 2.—(*Continued*)

Field	County	Pressure in Pounds per Square Inch[e]			Character of Gas Approx. Average During 1933	Producing Rock				Structure[j]	Deepest Zone Tested to End of 1933	
		Initial	Average at End of 1932	Average at End of 1933	B.t.u. per Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]		Name	Depth of Hole in Feet
S. W. Ontario................	Essex					Salina-Guelph	Silurian	L	Car	Af		
	Kent	650	215	207	1,060	Salina-Guelph	Middle Silurian	L	Car	Df	Pre-Cambrian	3,998
	Lambton	750	500	?		Salina-Guelph	Middle Silurian	L	Car	F	Trenton	4,420
	Middlesex					Grimsby?	Lower Silurian	LS	Por	Mc	Pre-Cambrian	3,755
	Elgin					Clinton	Lower Silurian	L	Por	Mc	Pre-Cambrian	3,585
	Norfolk					Medina Cataract	Lower Silurian	L and S	Por	Mc		
	Haldimand					Medina Cataract	Lower Silurian	L and S	Por	Mc		
	Wentworth					Medina Cataract	Lower Silurian	L and S	Por	Mc	Pre-Cambrian	2,827
	Lincoln					Medina Cataract	Lower Silurian	L and S	Por	Mc		
	Welland					Medina Cataract	Lower Silurian	L and S	Por	Mc	Pre-Cambrian	3,362
	Brant					Medina Cataract	Lower Silurian	L and S	Por	Mc	Pre-Cambrian	2,712
	Bruce					Trenton	Ord.	L	Por	?	Pre-Cambrian	1,678
	Peel					Dundas	Ord.	Sh	Por	?	Dundas	606
	Miscellaneous											

the more northerly part of Turner Valley one reached production in the Paleozoic limestone and the other obtained crude oil in the Lower Cretaceous, McDougal-Segur sand. A great stimulus to drilling in the southern end of Turner Valley was provided by the completion of Freehold No. 4 well in March, which reached the Paleozoic limestone at a depth of 5402 ft. and was completed at a depth of 5854 ft. A measurement of the well made on March 6 showed 14,750 M. cu. ft. of gas and the well produced 445 bbl. of naphtha in 24 hr. Miracle No. 2A well, completed in September on the west flank of Turner Valley, gave some new information in regard to expected production. The well reached the Paleozoic limestone at 5940 ft. and was completed at a depth of 6723 ft. producing 6000 M. cu. ft. of gas and about 100 bbl. per day of 55° Bé. oil. From the previous drilling of two wells on the west flank of Turner Valley, with a production of crude oil instead of naphtha, as in most Turner Valley wells, it was inferred that there was an oil zone on the west flank underlying the gas-naphtha zone and in the same horizon. This seems to be confirmed by the production of oil from Miracle No. 2A well. If, as is believed by the writer, the migration of gas and oil in Turner Valley may be somewhat restricted in movement by strike faults, perhaps dividing the producing zone into several more or less separate areas, the accumulation of gas in the interior part of the field with the oil on the flank must have been largely completed prior to the faulting because very little oil other than naphtha has been obtained even in very low structural areas in the interior of the field.

Another well of great importance completed in the southern end of Turner Valley late in 1933 was that of Sterling Royalties, which reached the Paleozoic limestone at a depth of 4977 ft. and was completed at a depth of 5657 ft. with a gas flow of 30,000 M. cu. ft. at 980 lb. back-pressure and a naphtha recovery of 320 bbl. per day. The tendency in drilling in Turner Valley during 1933 has been toward a southward extension of the field. One well was located too far east and was abandoned at 4300 ft. On the east flank the productive Paleozoic limestone is sharply delimited above a great overthrust fault, which underlies the whole of Turner Valley.

Outside of Turner Valley there has been relatively little activity in the foothills. Hunter Valley Oil Co. is drilling a well 60 miles north of Calgary and 60 miles west on Red Deer River. The surface structure is a beautifully defined anticline which, if persistent to depth, appears favorable for oil and gas accumulations. About 3½ miles east of the well location is the outcrop of a low-angle fault which in places has a westward dip to the fault plane of less than 10°. The stratigraphic displacement by the fault is 4500 to 5000 ft., which means a tremendous total displacement along the fault if the fault continues westward from the outcrop at so low an angle. The total displacement could, however, be readily

explained if the plane of the fault west of the outcrop becomes steep. The trace of this fault on the foothills topography east of the well is very sinuous, as would be expected for a fault with such a low-dipping fault plane, but northward the fault takes on a straight course regardless of topography, indicating that the low-angled fault has passed into one of steep dip to the fault plane. It is believed that in this more northerly area erosion has removed the low-angled part of the fault, which thus passes downwards into a steeper, deeper part, which now outcrops on the surface as a fairly straight line. This deeper erosion to the north is apparently confirmed by the outcrop of two separate Paleozoic limestone areas in the foothills east of the strike and 15 to 20 miles north of the Hunter Valley location. If these conditions are so it is probable, therefore, that the plane of the low-angle fault east of the Hunter Valley well becomes steep east of the well location and hence the surface anticline on which the well is being drilled probably continues to depth with favorable prospects for oil and gas. If, however, the fault should remain low-angled as far west as the well location, it might cut off the Paleozoic limestone in which production prospects are considered most favorable. Problems of structure connected with low-angle faults in the foothills of Alberta are exceedingly difficult of correct interpretation at depth even when fairly complete surface data are available and drilling has shown that many areas that appear favorable on the surface are but parts of overthrust masses that continue to no great depth. The Hunter Valley area, therefore, is of great importance in relation to the future developments of the foothills because of the fact that the very prevalent low-angle overthrusts of the southern foothills appear to give place northwards to less numerous faults of this kind and more open folds. At the present time the well has reached a depth of about 2000 ft. and is drilling in Blairmore strata of Lower Cretaceous age.

Several wells have been drilled on the Plains of Alberta during 1933. In Athadome No. 2 well, drilled west of the town of Athabaska on Athabaska River, an oil horizon was encountered in the Grand Rapids sandstone of Lower Cretaceous age. The well is said to have had a potential yield of 20 bbl. a day. Deeper drilling through the remaining Lower Cretaceous into the underlying Paleozoic limestone produced no further positive results.

In southern Alberta Nordon Oil Corporation, as the result of a seismograph survey, drilled a second well on the Twin River structure. The results, however, were not as favorable as had been anticipated although some gas and oil were encountered just below the Paleozoic limestone, which was encountered at a depth of 3900 ft. In the Red Coulee field the completion of Devonshire well gave only a small gas and oil show and the well was abandoned. Farther east and north the Commonwealth Milk River well was abandoned at a depth of 5301 ft. after having passed

into strata definitely identified as Cambrian. Apparently in this area no Ordovician or Silurian are present and presumably Devonian strata rest on Cambrian beds.

In Saskatchewan a test well is being drilled for gas in the Dirt Hills area south of Moose Jaw. This area was reported on favorably by a seismograph survey. The well was shut down for the winter before conclusive results were reached, although some gas shows of small proportions were encountered. A well drilled on the Lone Rock structure in Saskatchewan a few miles east of the Ribstone structure of Alberta is said to have penetrated a gas sand, but no definite information is available. A well is being drilled for gas north of Lloydminster, Saskatchewan, but has not yet reached the prospective productive horizons.

An interesting test is being drilled in the Sage Creek area of Flathead Valley in southeastern British Columbia. Here copious seepages of oil issue from pre-Cambrian rocks, which are known to be overthrust on to Mesozoic and Paleozoic strata. The area of seepages is on a well defined dome in the pre-Cambrian strata and there are reasons to believe the doming is later than the overthrusting, which implies that the doming condition occurs beneath the overthrust fault in the Mesozoic and Paleozoic beds as well as above it. Thus the oil and gas which are escaping through fractures in the pre-Cambrian rocks are inferred to arise from below a great overthrust fault in a favorable structure in strata known to have oil and gas prospects. The depth to the overthrust is not known but probably is not less than 4500 ft. and may be considerably greater.

In Ontario some exploratory drilling has been done between the proved oil and gas fields of the southwestern peninsula of Ontario, and a certain amount of drilling has been done in the proved gas areas to maintain production. This latter drilling has been mostly in Haldimand, Lambton, Kent and Norfolk counties with smaller amounts in some other localities. In some of the older oil-producing fields wells have been reconditioned and chemically treated to increase the flow. The production of oil, although relatively small, is slightly more than in 1932, and it is remarkable that the largest production still comes from fields that were the first to be discovered and have been in continuous production for more than 70 years.

During 1933 the Canadian Seaboard Oil and Gas Co. abandoned its No. 1 well drilled at St. Gerard, Yamaska Co., Quebec, on the south side of St. Lawrence River. The well showed a remarkable thickness of lower Paleozoic strata beginning in Queenston (Ordovician) red shales and encountering a sandstone at what is considered to be the base of the Trenton at 5980 ft. Below this were strata presumably of Chazy age and the well was abandoned at 6160 ft. still in Paleozoic beds. A second test by the Seaboard and Alberta Gas and Fuel companies at

Ste. Angele de Laval, Nicolet County, reached the top of the Trenton limestone at 4930 ft. The Trenton limestone proved to be only 170 ft. thick, much thinner than in the St. Gerard well, and lay on a basal arkose 20 ft. thick, which in turn rested on pre-Cambrian rocks encountered at 5120 ft. A considerable volume of gas occurred in the lower part of the well but the flow was not sustained.

In New Brunswick magnetometric surveys started in 1932 in connection with oil and gas prospects of the Stony Creek area were continued in 1933. It is understood that as a result of these surveys some further drilling will be done to extend the present oil and gas field.

For statistical information the writer is indebted to William Calder, Department of Lands and Mines, Alberta; Col. R. B. Harkness, Commissioner of Natural Gas, Ontario; and Dr. J. A. L. Henderson, New Brunswick Gas and Oil Company, N. B.

Petroleum Development in Colombia during 1933

By O. C. Wheeler,* Toronto, Ont.

(New York Meeting, February, 1934)

The production of oil in Colombia during 1933 was at the lowest level since the completion of the loop of the Andian pipe line in 1927. The commercial production amounted to 13,157,641 bbl., all of which was produced from the Infantas and La Cira structures of the Tropical Oil Company.

One of the most important developments was the discovery of what may be commercial production on the Colombian Petroleum (Gulf) Company's Tarra anticline on the Barco Concession in eastern Colombia near the Venezuelan border. This promises to become the second commercially productive area developed in Colombia and, perhaps, one of major importance.

Applications made in 1931 for concessions under the new Colombian petroleum law were ratified covering the Putana application of the Tropical Oil Co. and others of local Colombian and French interests west of the Carare River. On none of these concessions has any development work yet been initiated.

South American Gulf Oil Company

The following information covering the activities of the South American Gulf Oil Co. was furnished by E. S. Bleecker, chief geologist of the company.

Magdalena Valley.—No development work was undertaken during the year either on the Valenzuela property acquired from the Colombian Syndicate or on the lands obtained from the Leonard Oil Development Co. near the Sogamoso River. The Valenzuela property was relinquished and a portion of the material was removed therefrom to the Leonard property near by.

Colombian Petroleum Co.—The Colombian Petroleum Co., controlled by the Gulf interests, pursued an active development campaign on the Chaux-Folsom or so-called Barco Concession in the Department of North Santander. The drilling of the first well was begun early in the year on the north Petrolea dome of the Tarra anticline and at 490 ft. a heavy flow of oil, gas and salt water was encountered. On blowing in unexpectedly, the well caught fire, and after being extinguished was controlled only by pumping large quantities of cement into the formation and plugging the well. The drilling of the second test, No. 1-A, approximately one kilo-

* Geologist, International Petroleum Co. Ltd.

meter south of the first well, is now under way and at the end of the year had reached a depth of 1542 ft. It is the intention to make this a test of the deeper formations; hence the upper zones productive in No. 1 were not produced. Locations for test wells 2, 3 and 4 have been made and the railroad extension completed to location No. 2.

In the northern part of the concession, a camp has been established on Rio Catatumbo, 31 km. upstream from the mouth of Rio de Oro, from which point a road will be constructed about 4 km. west to a selected drilling site on Rio de Oro anticline. This location is called Oro No. 2, being about 11 km. south from the old Oro No. 1 well drilled by Henry L. Doherty & Co. on the south bank of Rio de Oro, opposite the operations of the Colon Development Co. on the same structure where it extends into

TABLE 1.—*Oil and Gas Production in Colombia*

Line Number	Field and Department	Age, Years to End of 1933	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1933	Total Oil Production, Bbl.: During 1932	Total Oil Production, Bbl.: During 1933	Total Oil Production, Bbl.: Daily Average during Nov., 1933
1	Las Perdices, Atlantico	7	*x*		*x*	*x*	0	0	0
2	Tarra (Petrolea), Santander del Norte	1	*x*	*x*	*x*	*x*	0	*x*	*x*
3	Rio de Oro, Santander del Norte	13	*x*		*x*	*y*?	0	0	0
4	Las Monas, Santander	6	*x*		*x*	*y*?	*y*?	*y*?	*y*?
5	Infantas, Santander	15	5,300		5,300	83,926,519	9,479,430	7,217,655	18,246
6	La Cira, Santander	7	4,700		4,700	48,202,641	6,937,695	5,939,986	15,062
7	Colorado, Santander	6	*x*	*x*	*x*	1,901	0	0	0
8	Mugrosa, Santander	5	*x*		*x*	69,838	0	0	0
9	San Luis, Santander	8	*x*		*x*	7,996	0	0	0

[a] Footnotes to column headings and explanation of symbols are on page 175.

Line Number	Average Oil Production, Bbl.: Per Acre to End of 1933[b]	Average Oil Production, Bbl.: Per Acre-foot to End of 1933	Average Oil Production, Bbl.: Per Well Daily during Nov., 1933	Total Gas Production, Millions Cu. Ft.: To End of 1933	Total Gas Production, Millions Cu. Ft.: During 1932	Total Gas Production, Millions Cu. Ft.: During 1933	Total Gas Production, Millions Cu. Ft.: Maximum Daily during 1933	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[c]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing
1	*x*	*x*	0	*x*	0	0	0	2	0	0	2	0	0	0	0
2	*x*	*x*	0	*x*	0	*x*	*x*	1	1	1	0	0	0	0	0
3	*x*	*x*	0	*x*	0	0	0	1	0	0	1	0	0	0	0
4	*x*	*x*	*y*	*x*	*x*	*x*	*x*	4	0	0	*y*	*y*	0	0	*y*
5	15,835	*y*	99	*x*	11,809[1]	9,166[1]	*x*	449	0	0	324	272	0	0	272
6	10,256	*y*	173	*x*	7,381[1]	6,356[1]	*x*	215	14	1			0	0	
7	*x*	*x*	0	*x*	0	0	0	1	0	0	1	0	0	0	0
8	*x*	*x*	0	*x*	0	0	0	1	0	0	1	0	0	0	0
9	*x*	*x*	0	*x*	0	0	0	3	0	0	3	0	0	0	0

[1] Estimate or approximate.

Venezuela. Complete drilling equipment has been landed at the Catatumbo port and construction of the road to the location has been started.

Tropical Oil Company

The development on the Tropical's property was confined to the producing fields at Infantas and La Cira. There was no immediate need of new production; hence the drilling during the year was primarily for information on scattered parts of La Cira field. For the first year since the company has been operating, drilling was done exclusively by Colombian workmen and they acquitted themselves most creditably.

The decreased rate of production and the reduced development program permitted an increased efficiency in all lines of work.

Comments on Tables

For the sake of completeness, all fields that have produced oil in Colombia are listed in Table 1 although in only the Infantas and La Cira fields has commercial development taken place.

Table 1.—(*Continued*)

Line Number	Average Depth, Ft.		Oil Production Methods at End of 1933						Pressure, Lb. per Sq. In.[e]			Character of Oil Approx. Average during 1933				
			Number of Wells							Average at End of		Gravity A. P. I. at 60° F.				
	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Misc.	Injection into Reservoir[d]	Initial	1932	1933	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]
1	800[1]	800[1]						0	*x*	*x*	*x*			37(?)	*x*	*x*
2	490	490						0	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*
3	890	890						0	*x*	*x*	*x*	*y*	*y*	*y*	*y*	*y*
4	800–2,300	*y*						0	*x*	*x*	*x*	*y*	*y*	*y*	*y*	A
5	1,000–2,600	400–2,200	27	243	0	0	2	68	*x*	*x*	*y*	37	24	27	0.90	A
6	600–3,600	400–3,300							*x*	*x*	*y*	28	20	25	0.90	A
7	3,920	3,875						0	*x*	*x*	*x*	*y*	*y*	37.3	0.14	*y*
8	2,249	2,168						0	*x*	*x*	*x*	41.4	41.4	41.4	*y*	M
9	1,200	1,180						0	*x*	*x*	*x*	36	34.2	35	0.65	*y*

Line Number	Character of Gas Approx. Average during 1933	Producing Rock					Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933		Reference to Text[k]
	B.t.u. per Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average Feet			Name	Depth of Hole, Ft.	
1	*x*	*y*	Mio	S	*x*	*x*	A	6	Mio or U. Oli	3,030	O
2	*x*	*y*	Cre	*y*	*x*	*x*	A	0	Cre	1,542	A
3	*x*	*y*	*y*	*y*	*x*	*y*	A	0	*y*	890	O
4	*x*	*y*	Oli, Eoc.	S	*y*	*y*	AF	4	CreU	3,605	A
5	1,050	A, B and C Zones	Oli, Eoc.	S	15–22	60–300	AF	12	CreU	3,790	
6	1,050	A, B and C Zones	Oli, Eoc.	S	15–25	50–175	AF	1	CreU	3,536	
7	*x*		Oli	S	12	30	AF	6	CreU(?)	6,162	
8	*x*		Eoc	S	*x*	20	AF	3	CreU	5,665	
9	*x*		Oli	S	10	20	AF	3	CreU	4,688	

Los Perdices.—This field is near the coast close to Barranquilla. Drilling has been carried on by the Jenks Syndicate of London, operating under the name of the Colombian Oilfields, Ltd. There is no record of the amount of oil that has been produced from the two oil wells completed in the field, but it is known to be very small. The wells have never been commercial producers.

Tarra Field.—The possibilities of this field becoming an important oil producer were demonstrated by the Gulf's Petrolea No. 1, which blew out during the year. This was the first well drilled in Colombia on the Tarra anticline, which is a long uplift extending across the Venezuelan border.

TABLE 2.—*Summary of Drilling Operations in Colombia*
(Figures in body of tabulation represent number of holes.)

Department	Completed Prior to Jan. 1, 1934									Completed during 1933			Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes								Productive Wells (For Details See Table 1)	Dry and/or Near-dry Holes		Productive Wells		
	Total Depths, Ft.							Total		Total Depths, Ft.	Total	(For Details See Table 1)	Within Fields	Exploratory
	Under 1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000			3000–4000				
Atlantico and Bolivar (Exclusive of Sinu River Area)	6	6	2	8	4			26	2		0	0	0	0
Bolivar (Sinu River Area only)	1		5					6	0		0	0	0	0
Santander del Norte	1		2	1				4	2		0	1	1	0
Santander:														
(Lebrija River Dist.)	1	2	4	1		1		9	0		0	0	0	0
(Sogamoso River Dist.)			1	1	2	1		5	4		0	0	0	0
(Tropical Oil Co.)		2	5	8	3	3	1	22	668	1	1	14	4	0
Cundinamarca			1	3				4	0		0	0	0	0
Tolima	1							1	0		0	0	0	0
Total	10	10	20	22	9	5	1	77	676	1	1	15	5	0

Rio de Oro Field.—The single well that has been completed in Colombia on this structure was drilled in 1920 by the Henry L. Doherty interests and was reported to have produced approximately 1000 bbl. initially. Until recently, development was delayed owing to the uncertain status of the Barco Concession, but it is probable that the Gulf will be successful in further extending the field.

Las Monas.—No work has been done in this field for several years and the small production that has been developed has never warranted marketing. Operations in this field have been under the direction of the Leonard Oil Development Co. and, subsequently, of the Gulf Leonard Development Company.

Colorado, Mugrosa, San Luis.—These fields, which are on the Tropical Concession near the Infantas and La Cira districts, are light producers and are not commercial at the present time. Further development may take place on these structures if future conditions warrant.

Table 2 is believed to include all wells drilled for oil or gas in Colombia to the end of 1933. Any errors in the detail regarding this drilling are believed to be minor and of no fundamental importance.

Oil and Gas Production in Dutch East Indies and Sarawak

THE information in Tables 1 and 2, on the operations in the Dutch East Indies and North Borneo, has been kindly furnished to the Institute through the courtesy of Mr. J. August Kessler by Mr. B. H. van der Linden. It affords a very good picture of the situation in that region for the year 1933.

TABLE 1.—*Oil and Gas Production in Dutch East Indies and Sarawak*
BY B. P. M., THE HAGUE, HOLLAND

Administration	Age, Years to End of 1933	Total Oil Production, Bbl.				Average Oil Production per Well Daily during Nov., 1933, Bbl.	Total Gas Production, Millions Cu. Ft.	
		To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933		During 1932	During 1933
North Borneo	24	58,214,825	3,683,637	4,277,000	10,650	24	2,013	2,375
East Borneo	38	292,302,205	14,437,316	14,252,000	36,559	57	3,658	4,099
Ceram	37	4,141,519	285,330	262,000	632	23	36	36
Java	46	66,767,423	3,731,810	3,492,000	9,624	21	1,579	1,389
South Sumatra	37	107,245,102	7,586,912	7,646,000	21,511	71	3,034	2,823
North Sumatra	49	91,454,840	4,479,929	6,079,000	17,274	247	1,850	1,721
Total		620,125,914	34,204,934	36,008,000	96,250	50	12,170	12,443

Administration	Number of Oil and/or Gas Wells						Average Depth, Ft.		Oil Production Methods at End of 1933			
		During 1933		At End of 1933					Number of Wells			
	Completed to End of 1933	Completed	Abandoned	Producing Oil Only	Producing Gas Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift
North Borneo	502	16		443	1	444	340–5,280	130–5,242	11	415	18	
East Borneo	1,218 + y	12		641	1	642	230–2,620	210–2,600	12	605	25	
Ceram	73			28		28	260–1,020	240–1,000		28		
Java	1,348 + y	2		452		452	160–2,950	130–2,880	10	439	3	
South Sumatra	1,559 + y	3	3	304		304	290–5,400	160–5,200	63	72	169	
North Sumatra	706 + y	13	2	70		70	300–4,140	260–4,100	32	21	17	
Total	5,406 + y	46	5	1,938	2	1,940			128	1,580	232	

TABLE 1.—(*Continued*)

Administration	Producing Rock				Structure[i]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933	
	Name	Age	Character	Porosity, Per Cent			Name	Depth of Hole, Ft.
North Borneo...	Seria- and Miri Formations	Mio	SsH	18	AF	80	Seria deep shale	6,180
East Borneo....	Balik Papan-Poeloe Balang- Tarakan form.	Pli + Mio	SsH, S	10–30	Af	196 + y	Poeloe Balang	5,250
Ceram..........	Boela form. + Triassic	Pli + Tri	SsH	y	Af	40	Triassic	2,400
Java............	Mergelklei-, Globigerinae- Orbitoid zones	Pli + Mio	S, SH, LS	15–35	Af	306 + y	Basis mergel	5,900
South Sumatra..	Palembang and Telissa zones	Pli + Mio + Paleogene	S, SH, SS	13–28	Af	339 + y	Under Telisa	7,550
North Sumatra.	Seuroela-, Keutapang-, Grensklei-zones	Pli + Mio	S, SH, SS	y	Af	242 + y	Grensklei	6,680

[i] Explanation of symbols is on page 175.

TABLE 2.—*Summary of Drilling Operations in the Dutch East Indies and Sarawak**

BY B. P. M., THE HAGUE, HOLLAND

Administration	Completed Prior to Jan. 1, 1934										Completed during 1933					Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes									Productive Wells (For Details See Table 1)	Dry and/or Near-dry Holes				Productive Wells (For Details See Table 1)		
	Total Depths, Ft.								Total		Total Depths, Ft.						
	0–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000			1000–2000	2000–3000	3000–4000	4000–5000		Within Fields	Exploratory
North Borneo..	30	24	16	7	3				80	502					16	1	1
East Borneo...	92 + y	71 + y	25 + y	4 + y	2	2			196 + y	1218 + y					12	5	1
Ceram.........	34	4	2						40	73							
Java..........	217 + y	74 + y	10 + y	3 + y	1	1			306 + y	1348 + y					2		1
South Sumatra.	199 + y	106 + y	21 + y	8 + y	2	1	1	1	399 + y	1559 + y	1		2		3	1	3
North Sumatra	153 + y	49 + y	33 + y	2 + y	2	2	1		242 + y	706 + y				2	13	1	

Oil and Gas Development in France and Northern Africa

By H. de Cizancourt, Paris, France

(New York Meeting, February, 1934)

France

Pechelbronn.—So far Pechelbronn is the only producing district. Figures are given in Table 2 covering the main features of the field, but these figures call for the following remarks: First, Pechelbronn should not be considered as a single unit, it appears, but as a succession of small oil fields, each of which is affected by very variable conditions. Consequently, certain figures concerning production per acre, production per acre-foot, pressure conditions and thicknesses of oil sands would be so misleading that they have been omitted here. Second, as regards production methods, attention is drawn especially to the fact that 42 per cent of the oil is extracted by the use of shafts and galleries and the remainder by pumping wells.

Exploitation, formerly confined to Oligocene sands, has been extended recently to Jurassic and Triassic oil-bearing formations.

Gabian.—This small oil field, discovered in 1924, is almost exhausted. Exploitation to date is restricted to three wells. There were no drilling activities in 1933.

Exploration.—During 1933, two exploration holes have been started in France. The first, in the vicinity of Layelanet (Ariège) on the Dreuille anticline, has reached the depth of 2400 ft.; the second, in the Autun Permian Basin, is drilling at 1300 feet.

Northern Africa

Morocco.—Drilling operations have been on a large scale in Morocco. In the Gharb district (Souk el Arba area), the deepest well was abandoned in 1933 at 7014 ft. Small irregular productive horizons were encountered in the Miocene at shallow depth, oil and gas showing in the Eocene, but no commercial oil field has been discovered. In the Djebel Tselfat, near Petitjean, a small production of oil was obtained from a Jurassic horizon. In the meantime deeper formations are being explored and a new structure in the vicinity is being tested. In Eastern Morocco, a well is drilling near Taza. Production in Morocco, about 2400 bbl., has not been listed on Table 2, owing to its origin—exploration wells.

TABLE 1.—*Oil and Gas Production in France and North Africa*

Line Number	Field	Age, Years, to End of 1933	Area Proved, Acres	Total Oil Production, Bbl.			
			Oil	To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
France							
1	Pechelbronn,[1] Bas Rhin	198	7,400	12,400,000	525,310	558,670[2]	1,400
2	Gabian	9	30	148,933	3,924	3,004	*y*
North Africa							
3	Morocco						
4	Tliouanet, Algeria	19	14.8	179,500	6,915	4,270	
5	Tunisia						

Line Number	Average Oil Production, Bbl.			Number of Oil and/or Gas Wells					Average Depth, Ft.		Oil Production Methods at End of 1933						Pressure, Lb. per Sq. In.		
					During 1933		At End of 1933				Number of Wells							Average at End of	
	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov., 1933	Completed to End of 1933	Completed	Abandoned	Producing Oil Only	Total Producing	Bottoms of Productive Wells	To Top of Productive Zone	Flowing	Pumping	Gas-lift	Air-lift	Mining	Injection into Reservoir[d]	Initial	1932	1933
France																			
1	..	..	1.34	4,000*x*	106	50	651	..	1,279	...	..	651	..	..	3 pairs of shafts				
2	..	..	..	14	...	..	3	3	492	450	..	3	..	..	....	..	*y*	*x*	*x*
North Africa																			
3																			
4	*x*	*x*	*y*	83	...	..	6	..	330	...	1	5	..	..	....	A	*y*	*y*	*y*
5																			

Line Number	Character of Oil, Approx. Average during 1933					Character of Gas, Approx. Average during 1933		Producing Rock							Deepest Zone Tested to End of 1933	
	Gravity, A.P.I. at 60° F.															
	Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	B.T.U. per Cu. Ft.	Gal. Gasoline per M. Cu. Ft.	Name	Age[g]	Character[h]	Porosity[i]	Net Thickness, Average in Feet	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Name	Depth of Hole, Ft.
France																
1	17	34.4	27.3	0.08	M	*y*	*y*	Pechelbronn form. Lower Oligocene Middle Jurassic Upper Triassic	Oligocene	Ss L D	..	..	MF	2,000	Lower Triassic	3,434
2	34.8	37.	35.7	0.21	P	..	..	Triassic	....	D	..	..	A	.....	Sil	2,479
North Africa																
3																
4	39.	47.6	.....	....	P	*y*	*y*	Helvetien	Mio	Ss	*x*	*x*	D	67	Cretaceous	*y*
5																

[b] Footnotes to column headings and explanation of symbols are on page 175.
[1] Data compiled from J. Mena.
[2] Of which 319,260 by wells and 239,410 by shafts and galleries.

Algeria.—Although production has been carried out on a small scale in the small Tliouanet field, drilling activities remain at a standstill.

Tunisia.—In Sloughia, a first well was abandoned at 1608 ft. Two new holes have been located and are drilling.

TABLE 2.—*Summary of Drilling Operations in France and North Africa*

(Figures in body of tabulation represent number of holes.)

County	Completed Prior to Jan. 1, 1934										Completed during 1933										Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes									Productive Wells (For Details, See Table 1)	Dry and/or Near-dry Holes									Productive Wells (For Details See Table 1)		
	Total Depths, Ft.								Total		Total Depths, Ft.								Total			
	300–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000			300–1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000	6000–7000	7000–8000			Within Fields	Exploratory
France																						
Pechelbronn							y				5	41	10	1					57	48	24	12
Gabian	38	11	1						50	14												
North Africa																						
Morocco:																						
Gharb	34[1]	19	2	1	1			1[2]	58		4	4	1					1	10			1
Tselfat	21	1	1						22		6		1						7			3
Fez, Taza, etc	1			1					2													1
Algeria:																						
Tliouanet	62	5							67	16												
Chelif valley	14	8[3]	2	3	2				29													
Tunisia:	3	1	2			1[4]			7			1[5]							1			2
Total											15	46	12	1				1	75	48	24	19

[1] Partly for geological information only.
[2] 7014 feet.
[3] One of these wells in Aïn Zeft produced about 10,000 bbl. from 1904 to 1914.
[4] 5130 feet.
[5] 1608 feet.

Petroleum Development in Germany during 1933

By Walter Kauenhowen, Hamburg, Germany

(New York Meeting, February, 1934)

The production of crude oil in Germany during 1933 totaled about 1,669,521 bbl., a slight increase over the 1,608,558 bbl. produced in 1932. This is an extension of a yearly increase which has continued uninterruptedly since 1928. The 1933 increase in production is due chiefly to developments in the Nienhagen field. The production of the Wietze and Oberg fields remained rather stable, while the Oelheim-Eddesse and Volkenroda fields showed decreases.

Table 1.—*Oil Production of Germany by Fields and Oil Provinces, 1928–1933*
(Barrels of 42 Gallons)[a]

Year	Salt-dome Province					Thuringian Basin	Total Production of German Reich
	Nienhagen-Hänigsen Field	Wietze-Steinförde Field	Oelheim-Eddesse Field	Oberg Field	Total Salt Dome Fields	Volkenroda Field	
1928	274,323	322,742	679	46,319	644,021[b]		644,315[c]
1929	310,891	337,582	10,535	67,578	719,901[b]		720,069[c]
1930	586,404	427,539	100,716	72,485	1,186,969[b]	29,806	1,220,296[c]
1931	506,548	403,634	213,549	116,088	1,242,598[b]	360,885	1,602,517[c]
1932	769,405	366,982	230,979	130,711	1,498,077[b]	110,481	1,608,558[c]
1933	1,014,853	376,628	127,211	110,131	1,628,823[d]	40,698	1,669,521[d]

[a] Official figures published in Germany are given in metric tons. For the above conversion into barrels a factor of 1 metric ton equaling 7 bbl. has been used.

[b] Includes a very small production from Heide in Holstein.

[c] Includes a very small production from Tegernsee in Bavaria and Bruchsal in Baden.

[d] Preliminary official figures.

Producing Fields

Nienhagen Field.—This field furnished about 61 per cent of the total German oil production in 1933. Most of the drilling activity centered in the north district near the village of Nienhagen, where the trend of

developments is showing an easterly extension of the productive area which is following the strike of the northeastern flank of a west-northwesterly pitching upfold on the flank of the salt plug. During the year 19 wells were completed as producers, two wells encountered salt water, and four wells were temporarily shut down. At the end of the year 18 wells were drilling.

The bulk of the production was obtained from 65 wells producing from depths of 1950 to 4026 ft. The remainder of the production was supplied by about 100 shallow stripper wells.

Wietze Field.—This field produced about 23 per cent of the year's oil production. There were no developments of special importance. During the year seven shallow wells were completed and at the end of the year two were drilling. The number of producing wells is about 440. About one-half of the oil production of this field is said to be derived from wells, the other half by mining the oil sand.

Oelheim-Eddesse Field.—This field participated in 1933 with 7.6 per cent in the oil production of Germany. It consists of the old, nearly exhausted, shallow Oelheim district and the 1928 discovered Berkhöpen district, where production comes from the deep Rät sand. The production of the field seems to have passed its peak. Owing to the steep dip of the oil formation, the productive zone seems to be confined to a rather narrow strip. Wildcatting on other flanks of the salt plug has not yet been successful. At the end of the year in the Oelheim and Berkhöpen districts together 13 wells were producing.

Oberg Field.—The Oberg field supplied about 6.6 per cent of the German oil production. The most important feature during the year was the bringing in of the Otto III well, which forms a one-mile northward extension of the field. The eastern margin of the field was defined by several wells drilled near Münstedt, which encountered edge water. The limits of the field in the other directions are still unknown. While normal inside drilling has been going on, extension wells have been trying to outline the field in northeasterly and westerly directions. One well reached the deep Rät sand and found oil shows. Further testing of the Rät possibilities are being continued.

During the year 14 wells were completed as producers, four wells encountered salt water, and five wells were dry holes. At the end of the year nine wells were drilling and about 65 wells were producing.

Volkenroda Field.—The Volkenroda field yields 2.5 per cent of the German oil production. The oil is obtained from shallow wells which are drilled from the 3000-ft. level of a potash mine. Besides the yearly production figure, nothing has been reported officially about the developments in this field, and it is unknown whether the decrease of the production during 1933 is caused by natural decline or is due to the lack of drilling space within the mine.

Wildcat Activities

During the year 26 wildcat wells were drilled outside of the proven oil fields. In addition, 19 shallow core tests were drilled for determining structural conditions. Of the 26 wildcat wells, 21 were drilled in the salt-dome area, while five wells were drilled on Triassic anticlines with the Zechstein as the objective oil formation. A further analysis shows that five of the 26 wildcat wells were abandoned prematurely before having reached any known oil horizon. Of the remaining 21 wells, two were in localities where the objective sand was not sealed to form a trap, two wells were too low on the flanks to be tests of their respective structures, two found the objective sand to have been faulted out, six wells were not on favorable structure (wigglestick locations in part), four were too close to salt plugs to find favorable flank conditions, two wells found the objective oil zone to be too thin for commercial production, and three wells found small quantities of gas only.

At the end of 1933 a total of 24 wildcat wells were drilling, of which 19 wells were drilling on salt domes and five on Triassic structures (anticlines).

Geophysical Activities

During the year seismic reflection and refraction work as well as torsion-balance work was carried out especially in northwestern Germany, the purpose being to discover new salt domes and other structures, as well as to outline those already known. At present there are about 50 salt plugs in Germany of which the existence has been proved by drilling. Many of these have never been tested for oil, their existence being known only as the result of old potash explorations. In addition there are about 37 salt-plug prospects, which have been discovered by geophysical methods during the past few years.

Oil and Gas Development in Iraq, 1933*

By Ben B. Cox,† New York, N. Y.

(New York Meeting, February, 1934)

Since our last review of Iraq,[1] considerable progress has been made not only in exploiting Iraq's potential resources but in building pipe lines to carry the oil to the Mediterranean. No new fields were discovered in 1933. The Naft Khaneh field, discovered in early 1927 by the Khaniqin Oil Co. (subsidiary of the Anglo-Persian Oil Co.), continues to supply the local markets through the Rafidain Oil Co. Kirkuk field, discovered by the Turkish Petroleum Co. Oct. 14, 1927, remained shut in pending the completion of the Mediterranean pipe lines, and the Qaiyarah field, discovered by the same company on Oct. 13, 1927, was abandoned in 1928.

The principal development of interest during the year was the progress made on construction of the Iraq Petroleum Company's 1152-mile pipe line from Kirkuk to the Mediterranean. The line is double 10-in. and 12-in. pipe for 156 miles west of Kirkuk, where the parallel lines bifurcate, one leg going through British mandated territory to the new port of Haifa and the other through French mandated Syria to Tripoli. Each line may be operated independently of the other. There are three double stations on the Kirkuk-Haditha portion, four single stations on the Tripoli leg, and five on the Haifa in addition to a relief station in the Jordan Valley. Except for the Jordan Valley section and two other short stretches on the Haifa leg where pressures are exceptionally high, the line is single. Sea loading lines will be used exclusively at Tripoli and both sea loading lines and dock loading will be employed at Haifa. All pipe was welded and buried before the end of December, 1933. It is anticipated that enough stations will be completed to make 50 per cent capacity operation possible some time during the latter half of the current year. Some months will then be required in which to fill the line, so that if terminal facilities are ready and no unexpected emergencies arise, partial daily deliveries of Iraq crude may be received at the Mediterranean some time during the final quarter of the current year. Capacity operation of 84,000 bbl. per day is not anticipated much before the middle of 1935.

Oil and Gas Production

No gas is produced commercially and, except for Naft Khaneh production, no crude is marketed. Although the Turkish Petroleum Co. and

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* Published by permission of the Near East Development Corporation.

† Geologist, Near East Development Corporation.

[1] B. B. Cox: *Trans.* A.I.M.E. (1932) **98**, Pet. Dev. and Tech., 238-43. In 1933 (*Trans.*, **103**) E. B. Swanson reported on Iraq.

Iraq Petroleum Co. together have produced more than 2,000,000 bbl. from all areas since 1927, most has been returned to the reservoir through the wells. Iraq Petroleum Company's small skimming plant at Kirkuk supplies its operating requirements.

Drilling Operations

The Iraq Petroleum Co., since 1930, has discontinued exploratory drilling and concentrated on the exploitation of the Kirkuk field preparatory to filling its 84,000 bbl. pipe line. Drilling operations are on schedule and the I.P.C. expects to have its initial producing wells ready to turn into the line by April of this year.

The Mosul Oil Fields Ltd., holding company of all the shares in the British Oil Development Co., after acquiring the "West Tigris Concession" in May, 1932, has completed a geological survey of its 46,000 square miles and is entering upon an exploratory drilling program with three cable-tool rigs.

Petroleum in Iraq Transferred Territories in 1933*

The Khanaqin Oil Co., which operates the Naft Khaneh field in the so-called Transferred Territories, has continued to supply the Iraq market with petroleum products during the period under review. The output of its refinery at Alwand during the past three fiscal years ending March 31 has been as follows:

	Barrels of 42 Gallons Each, Year to March 31		
	1931	1932	1933
Gasoline	106,908	105,694	100,505
Kerosene	108,164	115,994	111,345
Fuel oil	365,500	392,819	413,966
	580,572	614,507	625,816

* Contributed by Anglo-Persian Oil Co. Ltd.

Summary of Producing Operations in Italy during 1933

By D. A. Greig,* Parma, Italy

(New York Meeting, February, 1934)

There was a decline in the Italian oil production in 1933 and also in the footage drilled. A total of about 194,500 bbl. of crude oil was produced in the Emilia district of northern Italy from the same fields in production as in 1932. New drilling to the extent of 80,700 ft. failed to find new production to compensate for the decline in old wells, and no new fields were discovered in spite of an active exploration campaign by the government-owned company A.G.I.P., which has just completed the first year of a five-year exploration program. This company drilled a total of about 33,000 ft. The majority of its tests were drilled in the Po Valley upon locations selected by geophysical methods. This company is changing over to the rotary system for all future wells. It produced about 16,600 bbl. of oil from wells near Salsomaggiore and in the Po Valley.

The Petroli d'Italia, which operates the old fields of Montechino, Valleja and Gratera south of Piacenza, has been doing normal development drilling in the endeavor to extend its present fields. Also it was drilling two exploration wells in the Torino district. It drilled a total of about 13,930 ft. and produced approximately 12,645 bbl. of very high-grade oil (specific gravity about 0.765).

The Società Petrolifera Italiana was occupied chiefly in exploratory drilling in the endeavor to extend its producing fields at Salsomaggiore and at Vallezza, south of Parma. It was also drilling one exploration well at Rile dell'Olio near Voghera on the line Milan-Genoa. It drilled a total of 33,849 ft. and obtained a production from its two fields of 165,273 bbl. It also produced 123,220 gal. of casinghead gasoline from Vallezza field absorption plant.

* Societa Petrolifera Italiana.

Petroleum Development in Mexico during 1933

By V. R. Garfias* and R. V. Whetsel,* New York, N. Y.

(New York Meeting, February, 1934)

The production of petroleum in Mexico during 1933 totaled 33,430,000 bbl., or 625,000 bbl. more than in the previous year. This is the first time since the peak in 1921 that the declining trend of output has been reversed. Drilling activity in the proven areas of the Isthmus of Tehuantepec and the Northern fields increased substantially during the year. The completion of two producers in the Poza Rica area south of Tuxpam and a shallow gas well in the Camargo district near the American border were the outstanding features of development.

Late in September the Northern fields and the oil port of Tampico were swept by a hurricane followed by floods which caused loss of life and heavy damage to the City of Tampico and to transportation, tank farms and refineries. For three weeks, owing to the silting of the Tampico Bar and destruction of terminal facilities, no oil could be shipped for export. About half the wells of the Northern fields were closed for a period of 30 days. The prompt and effective steps taken by General Macias, chief of military operations, prevented the spread of epidemics and any serious aftermath of the catastrophe.

Tables 1 to 3 give statistics on production, storage, exports and imports.

Table 1.—*Production*
(U. S. Barrels)

	Distribution of Production		Total Production Since Discovery to End of 1933
	1932	1933	
Northern fields	13,107,000	12,890,000	694,000,000
South fields	11,812,000	11,630,000	979,000,000
Tehuantepec fields	7,886,000	8,910,000	49,000,000
	32,805,000	33,430,000	1,722,000,000

* Foreign Oil Department, Henry L. Doherty & Co.

TABLE 2.—*Storage*
(U. S. Barrels)

	Jan. 1, 1933	Jan. 1, 1934
Heavy crude	7,553,000	7,790,000
Light crude	2,986,000	3,744,000
Fuel oil	1,877,000	1,843,000
Gas oil	409,000	558,000
Gasoline	493,000	570,000
Kerosene	283,000	540,000
Lubricants	170,000	152,000
Asphalt	183,000	115,000
Paraffin	453,000	357,000
Other distillates	1,840,000	1,639,000
	16,247,000	17,308,000

TABLE 3.—*Exports and Imports*
(U. S. Barrels)

	Exports[a]		Imports	
	1932	1933	1932	1933
Heavy crude	9,745,000	10,233,000		
Light crude		138,000	165,000	303,000
Fuel oil	7,382,000	5,621,000	527,000	907,000
Gas oil	1,087,000	1,125,000	100,000	18,000
Gasoline	2,133,000	1,986,000	378,000	53,000
Kerosene	1,011,000	543,000	9,000	
Lubricants	398,000	347,000	16,000	52,000
Asphalt	832,000	841,000		
Paraffin			9,000	8,000
Others			18,000	7,000
	22,588,000	20,834,000	1,222,000	1,348,000

[a] These figures include ships, bunkers distributed as follows:

	1932	1933
Fuel oil	1,594,000	1,456,000
Heavy crude	6,000	3,000
Gas oil	101,000	92,000
	1,701,000	1,551,000

Refining

In 1933 the amount of petroleum and its products treated in Mexican refineries increased about 12 per cent over 1932. During the year new units were installed in some of the larger refineries and their equipment improved. One small independent refinery was completed in Tampico.

Table 4.—*Runs to Stills and Refinery Output*
(U. S. Barrels)

	Runs to Stills		Refinery Output	
	1932	1933	1932	1933
Heavy crude	1,178,000	1,057,000		
Light crude	19,336,000	19,514,000		
Fuel oil	283,000	2,236,000	12,915,000	15,269,000
Gas oil	149,000	606,000	1,814,000	2,533,000
Gasoline	1,380,000	2,714,000	4,756,000	6,359,000
Kerosene	441,000	436,000	1,783,000	1,340,000
Lubricants	76,000	71,000	580,000	472,000
Paraffin	107,000	310,000	246,000	132,000
Asphalt			857,000	805,000
Other distillates	1,858,000	1,707,000	1,021,000	822,000
	24,808,000	28,651,000	23,972,000	27,732,000

Table 5.—*Domestic Consumption*[a]
(U. S. Barrels)

	1932	1933
Heavy crude	1,693,000	1,363,000
Light crude	258,000	333,000
Fuel oil	7,509,000	8,185,000
Gas oil	605,000	671,000
Gasoline	1,731,000	1,765,000
Kerosene	561,000	357,000
Lubricants	109,000	124,000
Paraffin	111,000	91,000
Asphalt	75,000	34,000
	12,652,000	12,923,000

[a] Consumption figures do not include bunker oil.

Oil Prices

The price of heavy crude f.o.b. Tampico declined from 44¢ U.S.Cy. per barrel at the beginning of 1933 to 36¢ in May. By July the price rose to 44¢ and in September advanced sharply to 70¢. At the close

of the year spot cargoes were selling at 74¢ per barrel compared to an average price of 44¢ in 1932, 55¢ in 1931, 60¢ in 1930, 65¢ in 1929 and $1.05 in 1928.

Southfield crude, chiefly bought in the field for local refining, sold at an average price of about 35¢ per barrel during the year.

Taxes

Table 6 shows Mexican oil taxes for December, 1932 and December, 1933. On Dec. 30, 1933, the government instituted a yearly surface tax, effective Jan. 1, 1934, of 20 centavos per hectare—about 2¼ U.S. cents per acre at the present rate of exchange—on all oil concessions granted to individuals or corporations. Slight increase in income tax rates was also enacted, including a new tax on incomes in the lower brackets.

TABLE 6.—*Mexican Oil Taxes*
(Dollars per U. S. Barrel)

	December 1932	December 1933
Heavy crude	0.08670	0.10646
Light crude	0.14618	0.17196
Fuel oil	0.12320	0.16321
Refined gasoline	0.12436	0.12786
Crude gasoline	0.27377	0.27335
Refined kerosene	0.08249	0.08635
Crude kerosene	0.17496	0.17709
Lubricants	0.16269	0.14805

The rate of exchange at the beginning of 1933 was approximately 3.25 pesos to the dollar, and toward the end of the year it declined to 3.60 pesos to the dollar. It is interesting to note that the sharp fluctuation of the American dollar had practically no effect on its relation to the Mexican peso.

Outlook for 1934

Higher prices for heavy crude may encourage drilling activity in the Northern fields during 1934 and present indications are that new development in the Poza Rica area will further increase the output of the South field, and as the fields on the Isthmus of Tehuantepec should maintain their present output, it is reasonable to expect that the production in 1934 will moderately exceed that of the preceding year.

Petroleum Industry in Persia in 1933*

(New York Meeting, February, 1934)

SINCE the comprehensive review of the Persian fields presented by Sir John Cadman last year,[1] operations have proceeded normally. No developments of especial importance fall to be recorded and it remains only to bring up to date the full information given at the beginning of 1933.

Controlled production from the Masjid-i-Sulaiman and Haft Kel fields has been maintained at slightly higher rates than during 1932. The figures for the past five years are as follows:

	Masjid-i-Sulaiman		Haft Kel	
	Tons	Barrels (approx. equivalent)	Tons	Barrels (approx. equivalent)
1929	5,434,071	41,531,828	(2 mos.) 26,884[a]	205,471
1930	4,925,869	37,647,713	1,013,433	7,745,523
1931	4,248,086	32,467,514	1,502,412	11,482,720
1932	4,490,010	34,444,759	1,955,798	14,926,511
1933	4,999,635	38,852,880	2,087,071	15,879,463

[a] Production to main pipe line from Haft Kel was begun in November, 1929.

These represent crude oil and products piped to the coast but exclude products reinjected into the reservoir, a process that has been in continuous operation at Masjid-i-Sulaiman during the period under review.

The systematic delimitation of the Haft Kel field has been continued during the past year and results have been sufficiently encouraging to justify the inception of a wider scheme for distribution of production.

Drilling has been resumed recently in the Persian sector of the Naft Khaneh field, and preliminary survey work is in progress for the selection of a site for a refinery at Kermanshah and the construction of a connecting pipe line.

Investigations in connection with the scientific control of reservoir were dealt with in considerable detail in last year's review. This work has been steadily pursued during 1933 and certain of the investigations have been the subject of papers presented to the World Petroleum Congress held in London in July of last year.

* Contributed by Anglo-Persian Oil Co. Ltd.

[1] *Trans.* A.I.M.E. (1933) **103**, 397.

Petroleum Developments in Peru during 1933

By O. B. Hopkins,* Toronto, Ont.

(New York Meeting, February, 1934)

There was no noteworthy development in the oil industry in Peru during 1933 and all activities were restricted to the producing fields. The output of the country increased above that of previous years but there still remained a substantial shut-in production at the close of the year. The total production during 1933 is estimated at 13,259,891 bbl., of which the International Petroleum Co., Ltd. contributed 11,205,-362 bbl. A relatively small amount of new drilling was undertaken during the year. The International completed only one new well although a number of the old producers were reworked and deepened.

Comments on Tables

There are four oil districts in Peru, as shown in Table 1, although only three of these are now being operated. The exhausted Pirin field was abandoned eight years ago.

La Brea-Parinas.—The La Brea-Parinas fields are on the property of the International Petroleum Co., Ltd. in the westernmost part of Peru. These fields include a number of producing districts that are defined by complex fault blocks associated with anticlinal folds. Data covering all the items listed in the table are not available on these fields but can perhaps be supplied in part in the future.

Lobitos and Restin.—These two fields belong to the Lobitos Oilfields Limited and are near the coast, 10 to 20 miles north of the La Brea-Parinas fields. According to the Department of Mines and Petroleum of Peru, 311 wells at Lobitos and 197 at Restin had been drilled to the end of 1927. Since that date there has been enough drilling to increase moderately these figures. The depth of wells is not available but it is believed that their average depth is slightly greater than in the La Brea-Parinas area. The productive horizons are of Eocene age.

Zorritos.—The Zorritos field is the northernmost in Peru and is operated by the Establecimiento Industrial de Petroleo de Zorritos. The field is on the coast about 70 miles north of Lobitos. The number of wells drilled in this field to the end of 1927 was 343, according to the Department of Mines and Petroleum of Peru. The depths of these wells are reported to range from 300 to 700 ft. The largest wells do not produce

* Chief Geologist, Imperial Oil, Ltd.

more than a few hundred barrels initially and usually less than 100 bbl. The amount of drilling since 1927 has been relatively small.

TABLE 1.—*Oil and Gas Production in Peru*

Line Number	Field and Department	Age, Years, to End of 1933	Area Proved, Acres: Oil	Area Proved, Acres: Oil and Gas[a]	Area Proved, Acres: Gas	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1933	Total Oil Production, Bbl.: During 1932	Total Oil Production, Bbl.: During 1933	Total Oil Production, Bbl.: Daily Average during Nov., 1933
1	La Brea and Parinas, Piura	Over 40				±13,500	119,654,506	7,635,681	11,205,362	33,268
2	Lobitos and Restin, Piura	28				y	31,842,873	2,212,811	1,994,700	
3	Zorritos, Tumbes........	49				y	est. 2,949,594	51,257	est. 60,829	
4	Pirin (Huancane), Puno..	27	Field abandoned in 1915.			y	285,936	0	0	0
	Total.................						Est. 154,732,909	9,899,749	Est. 13,259,891	

Line Number	Average Oil Production, Bbl.: Per Acre to End of 1933[b]	Average Oil Production, Bbl.: Per Well Daily during Nov. 1933	Number of Oil and/or Gas Wells: Completed to End of 1933 (Total Drilled)	Number of Oil and/or Gas Wells: During 1933: Completed	Number of Oil and/or Gas Wells: During 1933: Abandoned	Number of Oil and/or Gas Wells: At End of 1933: Temporarily Shut Down	Number of Oil and/or Gas Wells: At End of 1933: Producing Oil Only	Number of Oil and/or Gas Wells: At End of 1933: Producing Gas Only	Number of Oil and/or Gas Wells: At End of 1933: Total Producing	Average Depth, Ft.: To Top of Productive Zone	Oil Production Methods at End of 1933: Number of Wells: Flowing	Oil Production Methods at End of 1933: Number of Wells: Pumping	Oil Production Methods at End of 1933: Number of Wells: Gas-lift	Oil Production Methods at End of 1933: Number of Wells: Misc.	Oil Production Methods at End of 1933: Injection into Reservoir[d]	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F.: Maximum	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F.: Minimum	Character of Oil, Approx. Average during 1933: Gravity A.P.I. at 60° F.: Weighted Average	Character of Oil, Approx. Average during 1933: Sulfur, Per Cent	Character of Oil, Approx. Average during 1933: Base[f]
1	8,863	24	2,838	1	6	217	1,452[c]	13	1,465	± 1,800	23	1,395	34	217	116	48	14	38	0.05L 0.075H	A
2			See Text															36	0.064	A
3			See Text															38		A
4			See Text															36		P

Line Number	Character of Gas Approx. Average during 1933: B.T.U. per Cu. Ft.	Producing Rock: Name	Producing Rock: Age[g]	Producing Rock: Character[h]	Producing Rock: Net Thickness Average Feet	Structure[f]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name
1	1,100	Lomitos Cong. mostly. Some from Salina and Upper Negritos.	Eoc	S. and S.H.	200	AF	554	Upper Cretaceous
2			Eoc	S. and S.H.		AF		
3			Mio	S.H.		AF		
4								

[a] Footnotes to column headings and explanation of symbols are on page 175.

Pirin (*Huancane*).—This is an old field, which has not been produced since 1925. It is about 28 miles from the Port of Puno on Lake Titicaca. From 1908 to 1910 about 50,000 bbl. annually was produced from this field, and this represents the peak period of production. The field is

included in this summary solely for completeness; it was never of much importance.

TABLE 2.—*Summary of Drilling Operations in Peru*

(Figures in body of tabulation represent number of holes.)

Department	Completed Prior to Jan. 1, 1934								Completed during 1933		New Wells Drilling or Incomplete at End of 1933	
	Dry and/or Near-dry Holes							Productive Wells (For Details, See Table 1) Including 476 Exh. Prod.	Dry and/or Near-dry Holes	Productive Wells		
	Total Depth, Ft.						Total		Total	(For Details See Table 1)	Within Fields	Exploratory
	Less than 1000	1000–2000	2000–3000	3000–4000	4000–5000	5000–6000						
Department of Piura												
La Brea and Parinas Estate	110	206	152	68	13	5	554	2284	None	1	1	0
Lobitos and Restin Fields												
Department of Tumbes												
Zorritos Field	See Text											
Department of Puno												
Pirin (Huancane) Field												
Total												

Polish Producing Operations during 1933

By Charles Bohdanowicz, Warsaw, Poland

(New York Meeting, February, 1934)

Table 2 shows a comparison of the drilling and wells completed in the years 1932 and 1933 in the three mining districts of Poland.

Table 2.—*Wells Drilled and Completed in Poland*

	Total Meters Drilled		Total Wells Completed	
	1933	1932	1933	1932
Jaslo	28,444	25,267	62	58
Drohobycz	31,031	25,753	Boryslaw 9	14
			Outside 34	33
Stanislawow	6,923	7,458	6	10
Total	66,398	58,478	111	115

Table 3.—*Production of Recently Completed or Deepened Wells, Poland, Sept.* 1, 1933

	Average Daily Production, Initial rather than Settled, Bbl. per Day	Average Daily Settled Production per Well, Bbl. per Day
1. Jaslo district (av. of 8 wells)	4.9	1.85
2. Boryslaw (well Kleiner)	51.1	9.3
3. Mraznica (well Metan)	43.8	19.7
4. Tustanowice (well Emigesta)	54.7	12.8
5. Wankowa-Rypne (av. of 8 wells)	12.8	2
6. Stanislawow district (av. of 5 wells)	14.0	2.6

The most important decline in drilling activities during the past three years was in the Boryslaw-Tustanowice-Mraznica fields and at Bitkow in Eastern Poland. A small drilling increase in some fields of the Jaslo and Drohobycz districts, notably Wankowa, Ropienka and Rypne, cannot compensate in new production for the decline in the large fields.[1]

[1] See C. Bohdanowicz: Oil Fields of Poland. *Bull.* Amer. Assn. Petr. Geol. (1933) **17**, 1084–1097.

TABLE 1.—*Oil and Gas Production in Poland*

	Field	County	Age in Years to End of 1933	Area Proved in Acres				Total Oil Production, Barrels				Average Oil Production in Barrels		
				Oil	Oil and Gas[a]	Gas	Total	To End of 1933	During 1932	During 1933	Daily Average during Nov. 1933	Per Acre to End of 1933[b]	Per Acre-foot to End of 1933	Per Well Daily during Nov. 1933
J	Lip. Lib. Kryg. Kob.	Gorlice	69	1,062			1,062	3,922,000	122,100	143,190	370	3,692		1.0
J	Biecz	Jaslo	36	54			54	250,786	22,940	24,124	84	4,624		2.9
J	Harklowa	Krosno	63	124			124	1,568,060	76,368	73,260	196	12,645		1.6
J	Jaszczew-Roztoki	Jaslo-Krosno	24		74	272	346	185,924	26,232	29,008	79	2,512		8.0
J	Potok	Krosno	42		173		173	4,688,640	70,988	87,320	222	27,102		4.6
J	Toroszowka	Krosno	43		99		99	196,420	20,202	18,944	48	1,980		3.2
J	Krościenko	Krosno	45	86			86	912,460	39,220	42,328	46	10,800		2.5
J	Zmiennica-Strachocina	Brzozów	37	67		247	314	608,036	20,128	19,980	54	9,075		1.5
J	St. Wieś-Grabownica	Brzozów	37		296		296	1,561,400	115,562	107,152	296	5,300		5.2
J	Weglówka	Krosno	45	156			156	1,878,860	28,712	28,860	74	12,044		0.9
J	Bóbrka-Równe	Krosno	75		198		198	5,236,980	109,776	85,100	212	26,450		2.8
J	Lubatówka-Wólka	Sanok	45	185			185	1,702,000	17,834	22,200	87	9,200		1.5
J	Zagórz-Tarnawa	Sanok-Lisko	52	50			50	1,157,796	2,146	1,776	5	23,155		5.0
Dm	Wankowa-Leszczowata	Lisko	47	220			220	3,997,575	116,175	123,825	358	18,173		2.0
Dm	Ropienka-Paszowa	Lisko	48	74			74	1,375,350	28,950	25,125	98	18,585		0.9
Dm	Rajskie-Polana	Lisko	47	40			40	55,725	3,525	3,375	5	1,115		0.5
Dm	Strzelbice	Stary Sambor	50	75			75	548,858	26,492	22,348	66	7,318		1.7
Dm	Schodnica-Urycz	Drohobycz	52	716			716	18,535,616	328,386	345,210	940	25,888		1.9
Db	Borysl. Tust. Mraz	Drohobycz	47	2,816			2,816	171,588,018	2,444,886	2,392,732	6,337	60,905		11.0
Db	Rypne-Duba	Dolina	46	150			150	1,648,276	142,450	152,440	438	11,000		4.0
Sb	Rosulna-Majdan	Bohorod-Kalusz	44	75			75	265,808	26,344	23,680	67	3,544		1.2
Sb	Bitkow	Bohorodczany	35	250			250	5,355,948	212,496	172,748	448	21,424		4.7
Sb	Pasieczna	Nadwórna	65	150			150	696,692	40,498	32,832	84	4,644		2.6
	Other Fields							?	77,022	113,163				
	Total—Barrels Tank Cars							227,937,228 3,080,232	4,119,432 55,668	4,090,720 55,280				

J = Jaslo district median zone.
Dm = Drohobycz district, median zone.
Db = Drohobycz district, marginal zone.
Sb = Stanislawow district, marginal zone.
Table compiled by Charles Bohdanowicz with the assistance of the Polish Association of Petroleum Engineers.

TABLE 1.—(*Continued*)

	Field	County	Total Gas Production, in Millions of Cubic Feet				Number of Oil and/or Gas Well								Depth, Average in Feet	
			To End of 1933	During 1932	During 1933	Maximum Daily during 1933	Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil Only	At End of 1933: Producing Oil and Gas[a]	At End of 1933: Producing Gas Only	At End of 1933: Total Producing	Bottoms of Productive Wells	To Top of Productive Zone
J	Lip. Lib. Kryg. Kob.	Gorlice		75		0.105	750	21		20	383		1	384	900	
J	Biecz	Jaslo		31	31		39	6		2	29			29	1,280	1,160
J	Harklowa	Krosno		40	42	0.122	253	6	9	14	121		1	122	1,000	700
J	Jaszczew-Roztoki	Jaslo-Krosno	56,575	1,841	1,855	0.173	42	10			3	7	17	27	3,000	2,900
J	Potok	Krosno		35		0.665	182	2	2	2		48		48	1,900	1,700
J	Toroszowka	Krosno		75	70	0.280	45	4	3	1		15		15	1,000	900
J	Krościenko	Krosno		12	12	0.080	106	2	2	6	47			47	1,300	1,000
J	Zmiennica-Strachocina	Brzozów	455	128	122	0.490	58		1	2	37		1	38	1,000	450
J	St. Wieś-Grabownica	Brzozów		450	455	1.330	100	6		10		56		56	1,800	1,600
J	Weglówka	Krosno		26	26	0.087	220		139	3	81			81	820	660
J	Bóbrka-Równe	Krosno		210	192	0.630	241	5	2	1	75			75	1,320	1,000
J	Lubatówka-Wólka	Sanok		58		0.157	75			3	58			58	1,300	1,200
J	Zagórz-Tarnawa	Sanok-Lisko			3	0.01	52		51		1			1	1,400	
Dm	Wankowa-Leszczowata	Lisko		41	42		164	11			175			175	1,450	
Dm	Ropienka-Paszowa	Lisko		12	12		147	8			109			109	1,050	
Dm	Rajskie-Polana	Lisko		1.7	1.7		20	1			12			12	1,100	
Dm	Strzelbice	Stary Sambor		9	9		47				38			38	880	
Dm	Schodnica-Urycz	Drohobycz		156	170		730	4			485			485	1,440	
Db	Borysl. Tust. Mraz	Drohobycz	1922–33 100,000	6,536	5,950	1.2	1,229	9	7		101	399	69	569	4,330	
Db	Rypne-Duba	Dolina		449	450		175	10			107			107	1,900	
Sb	Rosulna-Majdan	Bohorod-Kalusz					58				58			58	1,200	
Sb	Bitkow	Bohorodczany	22,686	1,660	1,435	0.04	155	4	4		6	85	11	102	2,720	
Sb	Pasieczna	Nadwórna		142	142		188	2			31		1	32	1,600	
	Daszawa			3,395	4,282											
	Other Fields						?							?		
	Total			15,424	16,316		5,076	111						2,668		

TABLE 1.—(*Continued*)

	Field	County	Oil Production Methods at End of 1933 — Number of Wells: Flowing	Pumping	Gas-lift	Air-lift	Miscel.	Injection into Reservoir[d]	Pressure in Pounds per Square Inch[e]: Initial	Average at End of 1932	Average at End of 1933	Character of Oil, Approx. Average during 1933 — Gravity, A. P. I. at 60° F.: Maximum	Minimum	Weighted Average	Sulfur, Per Cent	Base[f]	Character of Gas, Approx. Average during 1933: B.t.u. per Cu. Ft.	Gals. Gasoline per M. Cu. Ft.
J	Lip. Lib. Kryg. Kob.	Gorlice		375			8	3				30	37	34		P	1,124	
J	Biecz	Jaslo		29										41		A	1,124	
J	Harklowa	Krosno		116				6				11	28	27		A	1,011	
J	Jaszczew-Roztoki	Jaslo-Krosno						10	1,420		710	36	41	38	0.1	A	1,011	
J	Potok	Krosno		48		2			85			34	45	40	0.09	A	1,011	
J	Toroszowka	Krosno	1	14					497	128	128	38	51	45		A	1,011	
J	Krościenko	Krosno		47						71–142	71–142	29	34	33	0.09	A	1,124	
J	Zmiennica-Strachocina	Brzozów		32		6			1,278	710	710	34	36	35		P	955	
J	St. Wieś-Grabownica	Brzozów	2	22	2	5	25		497–710	71	71	39	60	49	0.08	A	1,067	
J	Weglówka	Krosno		81								32	33	32	0.13	P	1,124	
J	Bóbrka-Równe	Krosno		50			25		710	639	428	31	37	34	0.1	M	1,124	
J	Lubatówka-Wólka	Sanok		55			3					17	49	29		A	1,124	
J	Zagórz-Tarnawa	Sanok-Lisko		1										43		A		
Dm	Wankowa-Leszczowata	Lisko		172			3							32	0.2	P		
Dm	Ropienka-Paszowa	Lisko		109								31	37	34		P M		
Dm	Rajskie-Polana	Lisko		12								38	49			P A		
Dm	Strzelbice	Stary Sambor		38								31	33	32		P		
Dm	Schodnica-Urycz	Drohobycz		485				11				28	44	42		A		
Db	Boryslaw Tust. Mraznica	Drohobycz		37			532					31	35	34	0.25	P	1,461	
Db	Rypne-Duba	Dolina		104			3					36	38			A		
Sb	Rosulna-Majdan	Bohorod-Kalusz		48			10							38		A		
Sb	Bitkow	Bohorodczany	7	3			92					40	45	42	0.32	P	1,067	
Sb	Pasieczna	Nadwórna	12				19					37	63	49		P M		
	Other Fields																	
	Total																	

TABLE 1.—(*Continued*)

	Field	County	Producing Rock: Name	Age[g]	Character[h]	Porosity,[i] Per Cent	Net Thickness, Average in Feet	Structure[j]	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested to End of 1933: Name	Depth of Hole in Feet
J	Lip. Lib. Kryg. Kob.	Gorlice	Sandstone	Eoc. cr.		25	80	A.M.			
J	Biecz	Jaslo	Sands. Ciężkow	Eoc.			120	diap.			
J	Harklowa	Krosno	Sands. Krosno	Olig.			150	A.			
J	Jaszczew-Roztoki	Jaslo-Krosno	Sands. Ciężkow	Eoc. cret.			245	diap.	7	Sand III cretac.	3,895
J	Potok	Krosno	Sands. Ciężkow (I–II)	Eoc.			198	diap.			
J	Toroszowka	Krosno	Sands. Ciężkow (I–II)	Eoc.			80	A.F.	20		
J	Krościenko	Krosno	Sands. Ciężkow II	Eoc.			190	diap.			
J	Zmiennica-Strachocina	Brzozów	Sands. Ciężk. I gas II	Eoc. cret.			100	diap.		Sand II cret. gaseous	2,640
J	St. Wieś-Grabownica	Brzozów	Sands. Ciężk. I cret. II	Eoc. cret.			200	diap.			
J	Weglówka	Krosno	4 horiz. cretac.	Cret.			100	A.M.	13		
J	Bóbrka-Równe	Krosno	Sands. Ciężk. I–III	Eoc.			160	A		Sand IV	3,735
J	Lubakówka-Wólka	Sanok	Sands. Ciężk. I–III	Eoc.			132	A		Sands. Ciężkow	3,195
J	Zagórz-Tarnawa	Sanok-Lisko	Sands. Krosno	Olig.				A.F.			
Dm	Wankowa-Leszczowata	Lisko	Sand. Krosno low. and Menil. upp.	Olig.				diap.		Cretaceous	3,208
Dm	Ropienka-Paszowa	Lisko	Sand. Krosno low. and Menil. upp.	Olig.				diap.		Eocene	3,238
Dm	Rajskie-Polana	Lisko	Sand. Krosno low. and Menil. upp.	Olig.				A.F.			
Dm	Strzelbice	Stary Sambar	S. Eoc. Jamn	Eoc. cret.				A.		Eocene	1,986
Dm	Schodnica-Urycz	Drohobycz	S. Jamna	Cret.				A.F.		Cret.	3,232
Db	Borysl. Tust. Mraz	Drohobycz	I–VI hor.	Ol. cret.		10-15		A.F.		Cret.	6,626
Db	Rypne-Duba	Dolina		Olig.				A.F.		Eocene	4,190
Sb	Rosulna-Majdan	Bohorod-Kalusz	I–II hor.	Eoc.				A.F.			
Sb	Bitkow	Bohorodczany	I–IV hor.	Olig.				A.F.		Eocene	4,845
Sb	Pasieczna	Nadwórna	II–IV hor. O. hor.	Ol. cret.				A.F.		Olig.	5,117
	Other Fields										
	Total										

The large amalgamated firm of Malopolska produced 42.4 per cent of the 1932–1933 production and other large firms produced 29.8 per cent and small companies 27.8 per cent. In drilling activity the Malopolska showed 29 per cent, other large firms 8 per cent and small companies 63 per cent. The drilling activity of the small companies was almost entirely limited to the old small fields of the Jaslo and Drohobycz districts where large numbers of pumping wells produce a few barrels a day.

The small production from Polish wells is shown by the figures from different districts given in Table 3. Table 1 gives a detailed statement of oil and gas production in Poland.

The production of gasoline was 38,833 tons in 1932 and 41,978 in 1933. The production of ozokerite was 589 and 366 tons respectively.

The foregoing shows that the producing situation in Poland is becoming increasingly difficult, especially for all the larger companies.

Rumanian Oil Fields in 1933

(New York Meeting, February, 1934)

THE following have been compiled from information furnished through the courtesy of Dr. W. P. Haynes, of London, and Mr. T. V. Grigorescu of Ploesti, Rumania.

Gura Ocnitzei was the most active field during the year, furnishing 40 per cent of the production and 50 per cent of the drilling activity. Extensions to the west in this field were made both by Concordia and Romana Americana. In these new extensions the bulk of the production comes from the Drader member of the Dacian, with an average depth of 1300 m.; the underlying third Meotic at 1700 m. has not been developed yet. In Gura Ocnitzei east no new drilling has been done in 1933, but here declining pressures have led to the extensive use of gas-lift and pumps.

Ochiuri saw some small drilling activity, but production declined. Two good wells were brought in by Unirea and Astra at the close of the year.

Boldesti continued to be developed on a general plan by the four major companies interested. Production was from the Meotic, which in this dome has been penetrated for 356 m. Reserves have been estimated at about 63,000,000 bbl. An important discovery in this area was the bringing in of Credit Minier No. 1 Harsa to the east of the main field and producing from the Meotic. This well came in during October, 1932, and is now making 1400 barrels.

In the Moreni Piscuri field only routine operations have been carried on. The prolific sands are now declining rapidly. Ceptura also saw only routine operations.

In the Arcesti field development of the Meotic continues. Seven new wells were brought in during the year and ten were drilling at the close of 1930. The field produced over a million barrels for the first time during 1933.

In the other fields only routine operations were carried on.

A considerable increase in efficiency of operations was noted during the year. The average drilling time has been reduced, coring programs have been amplified, and much care has been taken in straight hole drilling. The Schlumberger electrical coring apparatus is extensively used. Electric-driven rotaries have been introduced at Gura Ocnitzei. The *Moniteur du Pétrole Rouman* reports that the index cost of drilling one meter, taking 1929 as a base of 100, has been reduced to 32 in 1933.

Of this amount the division of cost is as follows: Casing, 43 per cent; wages, 6; materials and administrative cost, 18; tools, 11; amortization, 8; water and steam, 8; miscellaneous, 6. The old system of bailing wells is now almost a thing of the past, and the majority of wells are equipped with either gas-lift or pumps. In general, the old competitive Rumanian

TABLE 1.—*Oil and Gas Production in Boldesti and Ceptura Fields, Rumania*

Line Number	Field, *District*	Age, Years to End of 1933	Area Proved, Acres: Total	Total Oil Production, Bbl.: To End of 1933	During 1932	During 1933	Daily Average during Nov., 1933
1	Boldesti, *Prahova*	5	53,218	21,477,000	8,658,300	7,333,600	251,700
2	Ceptura, *Prahova*	9	1,843.75	19,830,075	2,826,750	3,235,050	965.3

Line Number	Average Oil Production, Bbl.: Per Acre to End of 1933 [b]	Per Well Daily during Nov., 1933	Total Gas Production, Millions Cu. Ft.: To End of 1933	Number of Oil and/or Gas Wells: Completed to End of 1933	During 1933: Completed	During 1933: Abandoned	At End of 1933: Temporarily Shut Down	At End of 1933: Producing Oil and Gas *c*	Depth Average, Ft.: Bottoms of Productive Wells	To Top of Productive Zone	Oil Production Methods At End of 1933, Number of Wells: Flowing	Pumping	Gas-lift and Air-lift
1	27,000	695	1,207+	49[1]	11	5	3	36	8,202	7,546	32		4
2	18,930	219		181	5	16	9	44	3,609	2,953	13	23	8

Line Number	Character of Oil Approx. Average during 1933: Gravity A.P.I. at 60° F.	Producing Rock: Name	Age *g*	Net Thickness, Average Feet	Structure *j*	Number of Dry and/or Near-dry Holes to End of 1933	Deepest Zone Tested To End of 1933: Name	Depth of Hole, Feet
1	35.5	Upper and Lower Meotic	Pli	771	A		Lower Meotic	8,202
2	33.5	Upper and Lower Meotic	Pli	850	A[2]	38	Sarmatic	3,855

[b] Footnotes to column headings and explanation of symbols are on page 175

[1] Producing gas only, 4; dry holes, 2.

[2] Diapir type.

fields are producing a smaller and smaller percentage of the oil and the more recent discoveries, such as Boldesti and Arcesti, are being developed according to fixed plans.

TABLE 2.—*Production and Drilling, Rumania,* 1933.

Field	Age of Field, Years	Total Production, Bbl., 1932	Footage Drilled	Well Situation, Dec. 31, 1933		
				Drilling	Producing	Repairing
Gura Ocnitza	50	24,059,143	398,717	32	252	12
Ochiuri	19	4,449,569	55,075	2	70	2
Rasvad		175,704	29,628	6	2	
Glodeni	73	46,443			3	
Total Dambovitza District		28,730,859	483,420	40	327	14
Moreni	50	6,084,959	17,896		216	10
Piscuri		2,878,872	56,570	11	41	2
Boldesti	5	6,987,567	88,160	6	31	
Ceptura	9	3,234,623	11,998		49	
Runcu-Scorteni	21	1,276,624	35,467	6	97	6
Chiciura	21	1,002,086	2,260	1	148	16
Bustenari	50	388,039	226		268	15
Bordeni-Recea		16,337	2,424	1	10	2
Aricesti	1	1,163,248	114,052	10	6	2
Baicoi	70	428,320	3,559	1	35	4
Tintea	70	321,565			26	5
Campina	50	247,039			66	
Filipesti de Padure	23		1,072	1		1
Copaceni		163,148	2,017	1	5	1
Scaiosi and Udresti		14,126			3	
Wildcat wells		24,206,553	4,028	2		
Total Prahova district			339,749	40	1,001	64
Buzau district		484,158	1,827	1	84	
Bacau district		420,436	3,047	2	162	1
Neamtz district			2,965	1		
Total, Rumania		53,842,006	831,008	84+	1,574	79

	In 1932	In 1933
Natural gasoline production, gallons	60,250,801	59,650,718

The Petroleum Industry of the U.S.S.R.

(New York Meeting, February, 1934)

Foreword

The following paper, submitted by the Russian petroleum authorities, was secured through the courtesy of G. V. Ackerman, Vice President of Amtorg Trading Corporation, and N. V. Vannikoff, Representative in the U.S.A. of the United Oil and Gas Industries of the U.S.S.R. It gives an excellent view of the Russian petroleum industry as seen through Russian eyes. Noteworthy is the tremendous area over which the Russians are searching for petroleum, for this paper refers to such far-flung areas as the Arctic Tamir Peninsula, Kamchatka and Sakhalin on the Pacific, Lake Baikal in Central Siberia, the great new discovery at Neftadag in the plains of West Turkestan, and the oil of the Ferghana oasis, where the derricks look out over to the mosques of Kokand. Of interest also is the new pipe line to supply the industrial centers of Ukraine grouped around the great hydroelectric plant built at Dneprotroy on the falls of the Dnieper. The technical achievements have been noteworthy and we must pause to consider the scope of the undertakings being carried forward. Russia is at the worst a good second to the United States in petroleum reserves and for a long time to come will be a most important factor in the petroleum markets of the world. Her story should be of interest to everyone in the industry.

The First Five Year Plan

The first Five Year Plan, covering the period 1928–29 to 1932, accomplished the task of transforming the Union of Soviet Socialist Republics from an agricultural, backward land into a powerful independent industrial country, with an advanced technological foundation of its own for finally achieving the social reconstruction of the entire national economy. Along with the gigantic forward strides in industry and transportation, radical changes took place in agriculture. The creation of more than 5000 great state farms and of more than 200,000 collective farms serviced by a widespread network of machine-tractor stations has brought the U.S.S.R. to the fore as the largest agricultural country in the world. Imports of tractors and other agricultural machinery in the initial years of the Five Year Plan and the intensive output of this equipment by the great plants of the U.S.S.R. in the latter years of the plan have brought about the mechanization of agriculture in the Soviet Union. This year 250,000 tractors and 30,000 combines will operate in the fields

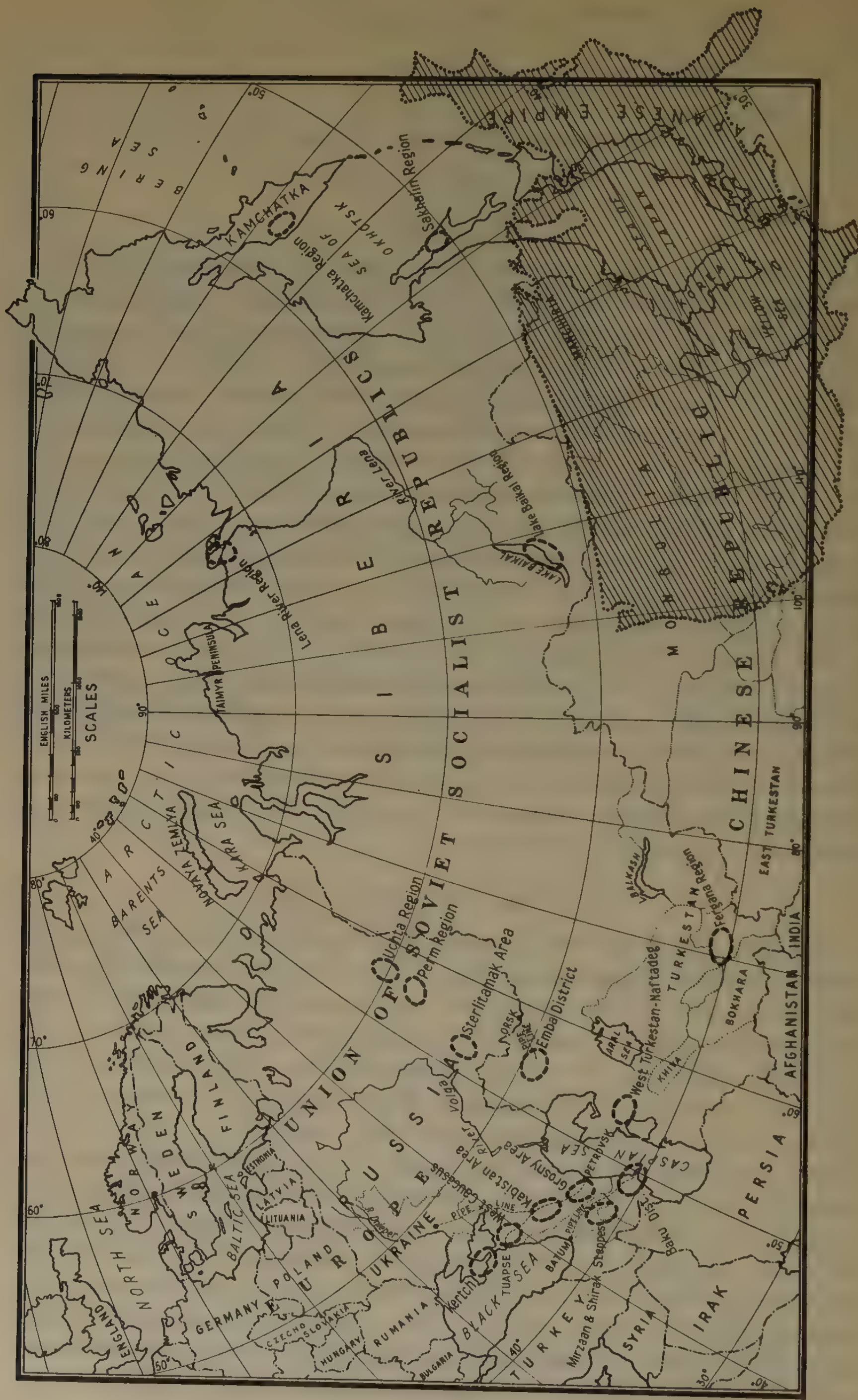

FIG. 1.—OIL FIELDS OF THE U.S.S.R.

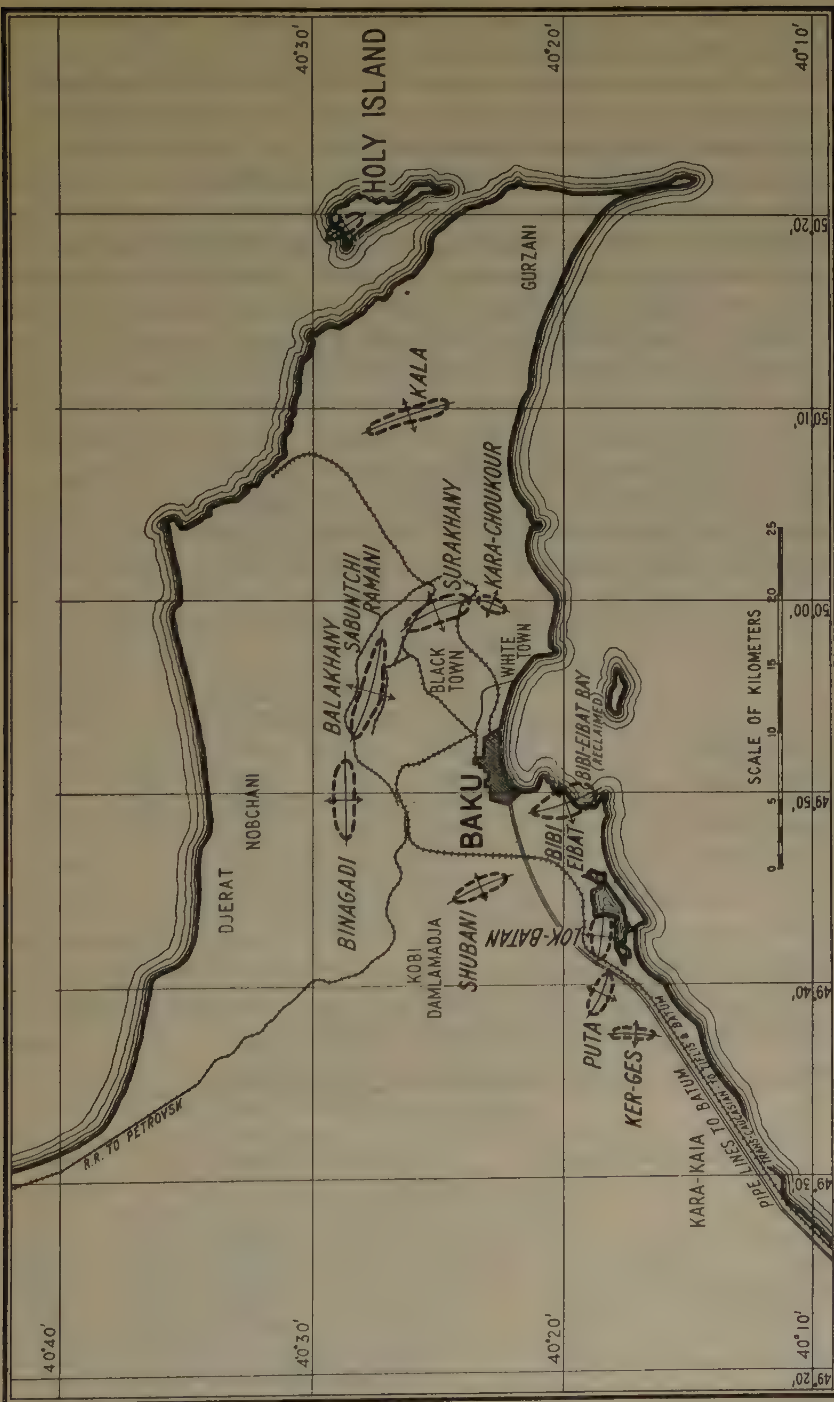

Fig. 2.—Oil fields of the Apsheron Peninsula, Caucasus—U.S.S.R.

of the U.S.S.R., with a per unit productivity several times greater than that of the leading capitalist countries.

Under these circumstances the role of the oil industry has become more important in the national economy of the U.S.S.R. with each year of development: the gigantic strides taken in the industrialization of the whole country, the mechanization of agriculture, the extensive introduction of automobiles, tractors and airplanes in all branches of the national economy, the rapid growth of road building, the increase in the use of machines and mechanical devices, have all served to place the oil industry in the position of leader in the social reconstruction of the country. The successfully conducted geological researches in the vast fields of the Soviet Union were also effective in this direction; the discovery of new rich locations of crude oil considerably widened the raw-material base of the petroleum industry. Recent years have been marked by the discovery of highly productive oil fields.

The requirements of the country for all petroleum products are widening with exceptional rapidity, especially the demand for high-grade gasoline and lubricating oils, as witness the figures of Table 1.

TABLE 1.—*Internal Consumption of Basic Petroleum Products, U.S.S.R.*
Thousands of Tons

	1928	1929	1930	1931	1932
Total oil products	6,960	8,452	10,461	12,524	14,443
Gasoline and ligroin	106	147	265	647	895
Kerosene	1,264	1,676	2,190	2,608	3,026
Lubricating oils	169	225	324	426	541

It is clear, therefore, why the Soviet Government pays so much attention to the development of its oil industry. Large annual appropriations are made by the Government for seeking new oil fields and for the production, refining and transportation of oil. Capital investments for the first Five Year Plan are shown in Table 2.

TABLE 2.—*Capital Investments in Petroleum Industry, U.S.S.R.*
Millions of Roubles

Branch of Industry	1928–29	1930	1931	1932
Drilling	80.9	99.4	165.8	187.5
Production	17.9	20.0	23.6	23.3
Refining	36.3	82.5	65.0	84.5
Pipe lines (main)	27.8	17.4	27.0	24.2
Other branches	71.9	142.3	135.6	133.5
Total	234.8	361.6	417.0	453.0

Because of such large investments, the total capitalization of the oil industry doubled from 1928 to 1932, increasing from 980,000,000 to 1,780,000,000 roubles. The entire industrial set-up was renewed with these investments in the period following nationalization. In 1933 the petroleum industry of the U.S.S.R. obtained practically its entire production from wells drilled under the Soviet régime. The proportion of oil produced from the nationalized wells amounted to less than one half of one per cent. Of the total oil output more than 30 per cent came from oil-bearing areas which were entirely unknown before the revolution.

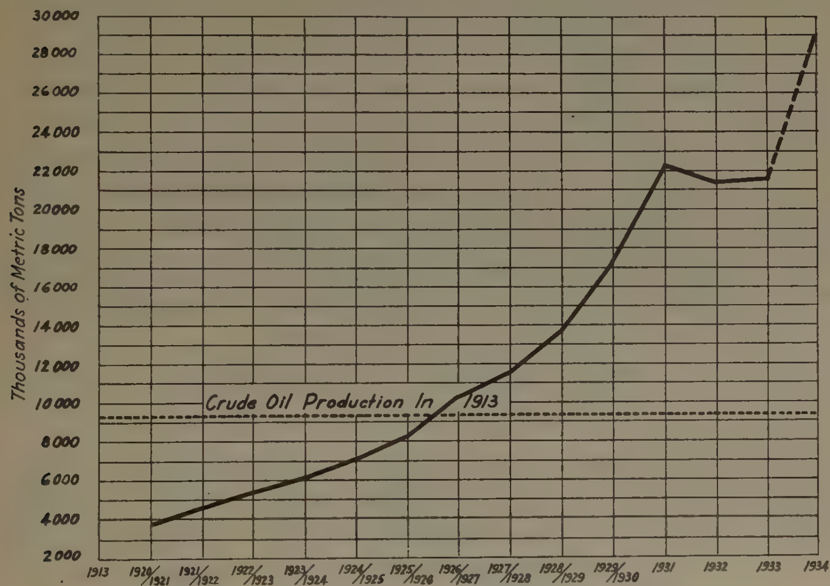

FIG. 3.—PRODUCTION OF CRUDE OIL, U.S.S.R.

The sustained technical reconstruction with the utilization of the technique and experience of the American petroleum industry enabled the oil industry of the U.S.S.R. to reach the pre-war level of production in the fiscal year 1926/27 and to exceed that level 2.3 times by the end of the Five Year Plan (1932).

TABLE 3.—*Oil Production in the U.S.S.R.*

Millions of Metric Tons

1913	9.2	1923–24	6.1	1927–28	11.6	1932	21.3
1920–21	3.8	1924–25	7.1	1928–29	13.7	1933	21.5
1921–22	4.7	1925–26	8.3	1929–30	17.3	1934 (Estimated)	29.2
1922–23	5.3	1926–27	10.3	1931	22.3		

The oil industry fulfilled its first Five Year Plan in 2½ years, reaching in the year 1930–31 a total production of crude oil and gas of 22.7 million

metric tons as compared with 21.7 million tons originally planned for 1932–33. Thus in 1933 the Soviet oil industry firmly established itself second to the United States in world oil production.

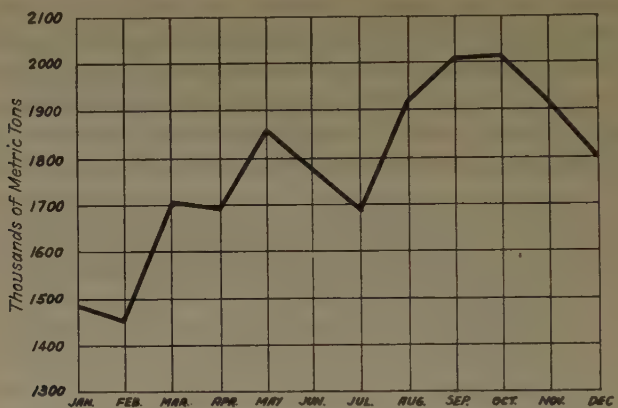

FIG. 4.—PRODUCTION OF CRUDE OIL, 1933, U.S.S.R.

For the five years 1928–29 to 1932–33 the oil industry produced about 100 million tons of crude oil against 85.6 million tons scheduled for the Five Year Plan.

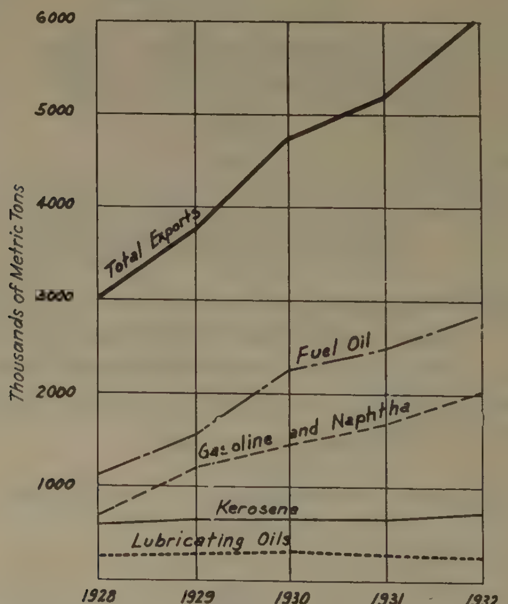

FIG. 5.—EXPORTS OF PETROLEUM PRODUCTS, U.S.S.R.

Very great changes occurred in the petroleum refining industry, especially in the last three years. Before nationalization the Russian oil industry did not possess a single pipe still or cracking unit. After

the nationalization the greater number of the old type of refining installations were reconstructed. In the last few years 22 new American-type atmospheric, atmospheric-vacuum, and vacuum type installations of large capacity were built, as well as 26 cracking installations, the greater part of which were of the Winkler-Koch type. In addition several installations in Saratov, Khabarovsk and Grozny are in the course of construction. The network of trunk pipe lines was augmented during the first Five Year Plan by the addition of two large crude lines and one kerosene line. The 10-in. pipe line from Baku to Batoum carries 1,640,000 tons per year; the second 10-in. crude line connecting Grozny and Touapse has an annual oil capacity of 1,650,000 tons.

The 12-in. line from Armavir to Trudovaya transports 1,640,000 tons of kerosene a year from the Grozny refineries to the consuming areas.

This development of the oil industry served not only to satisfy the growing demands of the domestic market but also to enlarge considerably the export of petroleum products.

The ratio of oil exports to the total exports of the U.S.S.R. increased from 13.8 per cent in 1927–28 to 18.6 in 1932. The growth and character of the oil exports of the Soviet Union are shown in Table 4.

TABLE 4.—*Oil Exports, U.S.S.R.*
Thousands of Metric Tons

	1928	1929	1930	1931	1932
Total oil products	3009	3835	4803	5280	6057
Gasoline and ligroin	826	1100	1470	1783	2005
Kerosene	743	782	777	729	793
Lubricating oils	250	261	272	261	249
Fuel oils	1190	1692	2282	2501	2928

Owing to the improvement in the operating methods and equipment employed in the petroleum industry of the U.S.S.R. there has been considerable progress in increasing the productivity of labor and in reducing cost of production.

In 1933—the first year of the second Five Year Plan—the Soviet oil industry made new gains, which were particularly evident in the accomplishments of Azneft—the unit of the Soviet oil organization in charge of the Baku region. Here there have been important results in the exploitation of the deep horizons in Surakhany (Ordzonikidze region), Bibi-Eibat (Stalin region) and Puta (Molotov region), and in 1933 new fields were placed in production—Kala (Azizbeikov region) and Lok-Batan (Mikoian region)—with powerful gushers that astonished the whole world. The result of the opening of these new fields was that Azneft exceeded its planned figure for the year of 14.4 million tons of crude oil, producing 15.3 million tons.

Of great interest also are the new oil fields in Grozny (Molgabek), Maineft (Khadyji), Embaneft (So. Iskin and Koschagyl), Turkmenneft (Neftedag) and Vostokneft (Sterlitamak). The total oil production in 1933 was 22.5 million tons (including gas) against 22.27 million tons produced in 1932.

TABLE 5.—*Crude Oil Production in the U.S.S.R. in* 1933

Thousands of Tons

January	1482	May	1862	September	2045
February	1453	June	1785	October	2086
March	1703	July	1695	November	1926
April	1695	August	1925	December	1800

The drilling operations in 1933 showed a decided increase. The total drilling in 1933 reached 838,000 meters, an increase of 13 per cent over 1932.

Basing the 1934 estimates on the 1933 production figures, plans have been laid for an output of 30.7 millions of metric tons (including gas). The plans for drilling call for 1,500,000 m. With the fulfillment of this plan the oil industry of the U.S.S.R. will have made another decided stride forward.

There has been a change in the geography of crude-oil production. Whereas before the revolution the main oil output came from the wells of the Caucasus, there are at the present time large new developments in the Ural Mountains, Emba, in Turkmaneft, and on Sakhalin Island and other places.

The second Five Year Plan contemplates further development of these new oil regions which have great political and economic significance.

OIL PROSPECTING IN U.S.S.R.

In the years immediately following the civil war the work of the geologists seeking new oil-producing areas was of a sporadic and scattered nature, consisting mostly of a continuation of previously started explorations or assignments from individual organizations or trusts.

The intensive prospecting in the areas already under production was started in 1924. Most attention was turned to the study of the deeper horizons. These explorations yielded the most excellent results: All oil-bearing strata of the Novo-Grozny region starting with stratum XIII, all of the Kirmakin strata in the region of Baku, oil-bearing stratum *S* of Maineft, and many others were uncovered during that period. During the same period there was organized a systematic geological service for all the various oil trusts for the purpose of deep drilling exploration.

The next step was the introduction of new methods of prospecting, using geophysics and shallow drilling. The geophysical method widely employed at Grozny and Emba quickly laid bare the formation and structure of the ground. The salt domes of Emba were discovered by

this method, and the structure of the vast area that stretches from the northern range of the Caucasus Mountains to the mouth of the Volga River was ascertained.

The last few years were characterized by the exploration of most areas of the Soviet Union. Geological expeditions in search for oil penetrated into the remotest regions of the country from the extreme northern points of Siberia, Kamchatka, mouth of the Lena River, Tamir, through Central Siberia to the semidesert places of middle Asia and Turkestan. The number of such exploration expeditions increased from 168 in 1931 to 330 in 1933, and at the same time these expeditions took on a more complex character; that is, each expedition was equipped and manned for performing topographical, geological, geophysical and drilling operations.

Deep-hole wildcatting is widely applied. There were 1,051 wildcats drilled in 1932.

Result of Geological Explorations

As a result of the geological explorations in the Azneft region a complete geological map has been made of the Apsheron Peninsula drawn to a scale 1/25,000, showing the newly explored anticlinal folds of Kala, Zikh, Mardakyani, Gurgyani, Turkyani, Kara-Chukhur, Sulu-Tepe, Lok-Batan, Puta, Ker-Gez. In addition, the geological structure of the Kabristan plains has been studied and favorable formations have been found—Kyaniz-Dag, Gengi, Cheil-Akhtarma, Solokhaya, Kari-Dag and places on the Alat ridge—Pirsagat, Bandovan, Khidirli. A general study was made of the lowland of the Kura River and favorable structures were found in the region of Agikabul.

In Georgia the explorations resulted in the uncovering of productive strata in the regions of Mirzaan and Shirak steppes. Favorable formations were found in the regions of Mlashis-Khevi, Kila-Kupra, Taribani, Tulki-Tapa, Chatma, Pkhoveli, Gurgaani, Navtlug, Ildokani. In Guria the structures of Ompareti, Guliani, Sakupra, Notanebi, Norio were studied.

In Turkmenia explorations were made in Neftedag, Boyadaga, Monzhykli, Sirtlali, Chikishlyari, Keimir and favorable structures were found in Mingishlak, with good indications of oil.

In Middle Asia there were found 53 structures with a considerable showing of oil in the regions surrounding the Fergan Valley. On the basis of geophysical data the great value of the Fergan Valley itself has been established and explorations for favorable formations is contemplated in the near future.

On the Kerch Peninsula 27 anticlines were studied and charted, the majority of which show signs of oil; nine folds were studied on the Taman Peninsula. In the western part of North Caucasus three folds in the region of Anop were studied and the structure of the following places was

ascertained: three Varenikov folds, Adagum, Kessler, Medovka, Kudano folds. Detailed information was accumulated regarding the structure of the Kholm, Ilsk, Kutais, Khadigin and Asphalt Mountain regions.

In the eastern section of North Caucasus the study of the following places was followed out: Mineralovodsk region, Stavropolsk region, Kalmik steppes, the Zaterek valley and also of a great number of folds (Datikhask, Kabardin, Sungen, Molgabek, southern and northern Voznesenki, Alkhazova, Eldarova, Goryachevodsk, Bragunsk, Gudermes, Benois, Nyatlinsk, Mutzidakal, Tushikli, Makhachkala, Izberbash, Achi-Sunsk, Kayakent, Dag-Ogni, Khotch-Menzil). In the region of Emba there were discovered 350 salt domes.

On the western slope of the Ural, deposits were uncovered in Ukhta, Chusovskie-Gorodki, Sterlitamak. The structure was studied at Samarski Luki, Sok, Urezan, Cherche, Keirovki, Ozinbe, Jelti and elsewhere.

The study of the Lake Baikal oil locations is being completed and a number of favorable structures and indications of oil were uncovered in Kamchatka in the region of Voyampolki, Tagil, Bogachev. Signs of liquid oil were found at the mouth of the Lena River on the Tamir Peninsula and on the Minusinsk steppes. On the island of Sakhalin signs of oil were discovered on the Schmitt Peninsula and the formation of favorable structures of Katangli, Garamai, Langeri, Ekhabi and Nutova, has been studied.

Industrial Results of Prospecting

In the Azneft region at Kala, Lok-Batan, Karachukhur, Puta, Kergez, Sulu-Tepe, Nefte-Chala and Naftalan drilling and production started immediately after the geological explorations. In the same region Pirsagot, Mardakyani and Zikh, having shown favorable structures, are being prepared for actual production. Some of the areas mentioned are already celebrated; for example, at Lok-Batan, which was discovered in 1932, five powerful gushers have been brought in. The total oil produced in this region in 1933 amounted to 646,300 metric tons. Of still greater significance is the Kala location, also discovered in 1932, the total output of which in 1933 reached 1.1 million metric tons. All the oil of these regions is from the so-called "productive layer," the total thickness of which exceeds 1500 m. Located near well-known productive oil fields of old standing, they have an almost identical cross-section. The sand saturation of Lok-Batan is the greatest ever known in the world. In Georgia a counterpart of the productive horizon of the Apsheron Peninsula has been found—the so-called Shirak continental formation—with a normal thickness of 2500 m., of which so far 1600 m. have been explored, containing 23 oil-bearing horizons with an aggregate thickness of 270 m. Two locations, Mirsanni and Shirocki, have been transferred to the regular production class, as some of their wells have flush production

and show abundant evidence of gas. The rest of the fields of Georgia are being wildcatted.

In Turkmenia exploration uncovered the region of Neftedag; the output of the thirteenth gusher was 250,000 metric tons of oil in 16 days, proving that the sand saturation of the eastern shore of the Caspian Sea is not less than that of the productive strata of Apsheron. Abundant oil and gas seepages and mud volcanoes scattered on the huge expanse of the western shore of the Caspian justify the belief that this area will come to the fore in oil riches.

Middle Asia so far has not given immediate productive results if we do not take into consideration the newly uncovered horizon *K* (lower Eocene), the enlarging of all the existing producing fields and the uncovering of Khanabad-Sai, proved so far by two producing wells. In the northern Caucasus the Molgabek region (Grozneft) was discovered and put in production, yielding three gushers with a daily production of 600 metric tons, and four oil-bearing strata of great potentiality were found. In the region of the Stara-Grozny the north flank of the oil-bearing strata of that region was discovered in a sealed state. A vast area, in the Benoisk fold, with a length of 20 km. was discovered, with a gusher flowing at a daily rate of 400 metric tons. In the near future the regions of Isberbash and Achi-Sunsk, which showed satisfactory signs of oil, will be put in production.

In the area of Maineft, oil was discovered in the Khadigensk region. Gushers were brought in from the Varenikov, Adagum, Kessler and Kudoko anticlines.

In the Emba region oil was discovered and operations started in South Iskin, Kos-Chagil, Shubar-Kuduk, Jakshilai, and Baichunas. Of these the first two yielded gushers of the order of 400 tons per day. In the Ural region, exclusive of the newly uncovered oil areas of Ukhta, Chusov-Gorodki, there were also found in 1932 rich new oil deposits in Sterlitamak (Ishimbaevo) in an area of 900 hectares with a number of gushers of 400 metric tons initial flow daily.

New Prospecting Methods

The geophysical method of prospecting came into extensive use in 1926. The application of this method was connected with the difficulties of exploration in places covered by deep topsoil, which hides from the geologist the true structure of the horizons lying below. The geophysical method used in U.S.S.R. differs from American practice in four respects:

1. Extensive use of pendulum observations as the first stage of geophysical exploration, which gives a clear picture of the distribution of heavy rock at great depths, and of any accumulations of sedimentary formations.

2. The application of varied geophysics in one and the same place. This method makes it possible to obtain more quickly a true picture of the subterranean cross-section.

3. Wide use of electric logging in the drilling of all wells, which not only reduces taking samples to a minimum, but also makes it possible to judge the condition of the strata as regards the degree of oil or water saturation, as well as salt concentration.

4. The method of gas analysis as the only means that would indicate directly the presence of gas and its composition, which in turn would signify the presence or absence of oil in the ground. It is our opinion that this method, for its simplicity and low cost, is far superior to any other known method.

The extensive use of the geophysical method required the importation from abroad of the necessary apparatus. At the present time 85 per cent of the equipment is manufactured in U.S.S.R.

The last few years were particularly successful ones in the Russian oil industry, for during that period a number of new, rich oil fields have been put into production. This success is largely due to the planned method of prospecting. The necessity of having sources of oil supply nearer to the country's industrial centers, and the growing demand for oil from Siberia, have compelled more attention to the possibilities of increasing the output of the Ural and Emba regions. At present the areas of Emba and Sterlitamak are great oil-producing areas, among the richest oil reserves in the world.

The success of our prospecting is due also to a large extent to the employment of the Complex method, by which all operations—geological explorations, geophysical investigations, shallow drilling and other work connected with prospecting—are carried out at the same time. This method makes it possible to save time and in the shortest time gives the answer to the question as to the value of a particular location.

Exploitation of the Oil Pools

Planning is the fundamental principle in the exploitation of Soviet oil pools. The Government monopoly in the exploitation of the country's oil pools, the absence of competition, the obliteration of frontiers between adjacent oil-producing areas, the doing away with private engineering and production secrets and the uniting of all geological exploration work under one management have helped to organize the oil industry as a whole and each of its separate units in accordance with *one plan* founded on the industrial-economic needs of the whole country and in accordance with the requirements of each particular section. The plan considers the whole petroleum industry, each of its producing fields, and each produc-

tive horizon of the field as one whole. Therefore, the exploitation of each pool is carried out in accordance with a system whereby the preservation of the country's natural reserves and the application of the most modern methods of operation are considerations of utmost importance. This system possesses great advantages; namely, (1) rational utilization of the inherent energy of each stratum; (2) elimination of the premature flooding of the strata; (3) the selection of a method of exploitation most suitable to the natural conditions of the given section, which leads to the reduction of drilling operations per unit of production, the reduction of capital investment, the increase of output and reduction of operating costs.

The question of choosing the most efficient methods of production has received the utmost attention in the Soviet Union. Along with the variety of methods for the drilling of one horizon, of which the hydraulic system introduced by I. M. Gubkin of the Academy in 1930 is of enormous practical value, there has been a wide application of the special system of wildcatting and production in oil-bearing layers of the vertical, so-called "snizuverkh" (from below upwards) system of Geologist M. V. Nikitin. By this system wells are first drilled to one of the lower horizons of the cross-section, the so-called "basic" horizon, and the succeeding wells are placed in the upper horizons while at the same time upon the exhaustion of the lower stratum it is possible to go over into production in the upper horizons which had been skipped. The system was applied with great effect in Bukhta (Bibi-Eibat) and is now applied in Surakhany, Kara-Kukhyr, in the Lenin fields and on the Island of Artem.

In recent years each pool has been worked in accordance with an individual plan in which, on the basis of the geological findings, calculated reserves and planned annual production, the order in which horizons are to be opened, order and rate of drilling of each one, the number of wells, their design, system of drilling and production, the general economics and investments in the pool are laid out in advance. The working out of such plans is facilitated in the U.S.S.R. by the highly efficient methods for appraising petroliferous formations, and estimating subterranean supplies of oil mathematically and statistically.

In the development of the Soviet oil industry, along with the achievements of the Soviet specialists, not a small share was contributed by American scientists. We are particularly indebted to Prof. L. C. Uren and Dr. S. C. Herold, who took active part in the discussion concerning the exploitation of oil beds at the last convention of the Union Scientific-Technical Society of Oil Engineers at Baku (August, 1933). The principles of Dr. Herold concerning the three methods of appraising an oil pool were adopted by the convention and are serving now as a basis for the study of oil pools.

Drilling

Characteristic of the development in the technique of drilling in the U.S.S.R. during the past decade is the replacement of percussion drilling (rod and cable) by the rotary method and partly by turbo-drilling.

Table 6.—*Drilling in U.S.S.R.*

Thousands of Meters

1913	276.6	1924–25	182.2	1930	639.3
1920–21	5.9	1925–26	287.9	1931	701.3
1921–22	19.1	1926–27	381.7	1932	743.1
1922–23	69.7	1927–28	362.1	1933	839.4
1923–24	123.2	1928–29	446.0		

By Months, 1933

January	48.5	May	66.3	September	93.4
February	51.5	June	60.1	October	91.9
March	71.3	July	63.8	November	83.7
April	72.1	August	72.3	December	64.5

Preceding nationalization the percussion method of drilling was used almost exclusively. Rotary drilling in Baku started on a very small scale in 1911–12. The early attempts to use rotary drilling in the oil fields of Grozny in 1903–10 were unsuccessful. The growth of rotary and turbo-drilling is shown in Table 7.

Table 7.—*Drilling Methods, U.S.S.R.*

Method of Drilling	Percentages of Use			
	1923–24	1928–29	1931	1933
Rotary and turbo-drilling	21	81	91	99
Percussion drilling	79	19	9	1

Average Drilling Speed (Meters) per Rig-month in Production Drilling

1913	1923–24	1925–26	1928–29	1931	1932	1933
34.6	41.5	55.7	79.4	108.5	149.3	185

The rate of drilling per rig-month is constantly growing. A considerable number of wells are being drilled at an average speed of 300 to 400 m. and higher per rig-month.

Drilling to a depth of 2000 to 2500 m. started in 1930. Deep drilling met with considerable difficulties caused among other things by cave-ins at 1500 to 2000 m. In many cases it was necessary to overcome many complications at one time: the inflow of hot water under a pressure of 200 atmospheres, appearance of gases and caving. The deepest well in U.S.S.R. was drilled in 1932–33 by the rotary method in Dossor in the region of Ural Emba. The depth was 2840 meters.

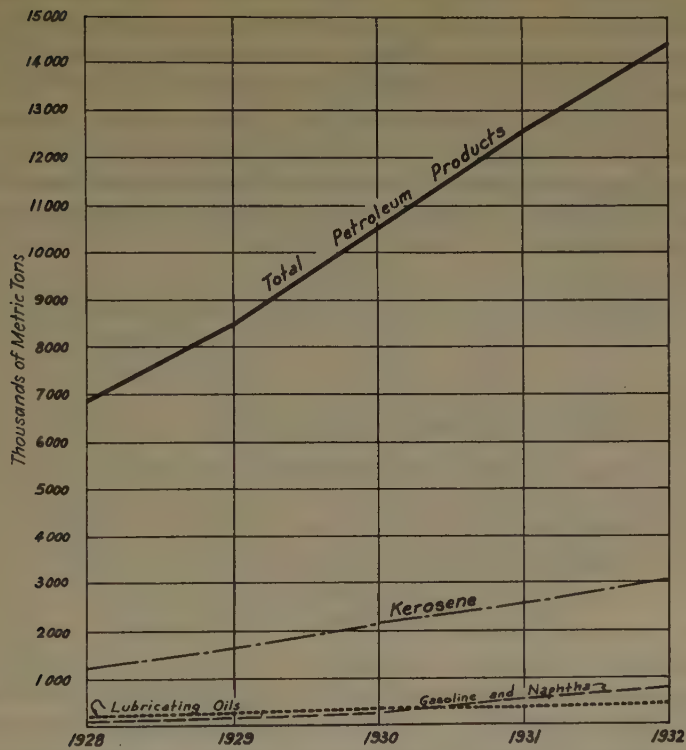

Fig. 6.—Domestic consumption of petroleum products, U.S.S.R.

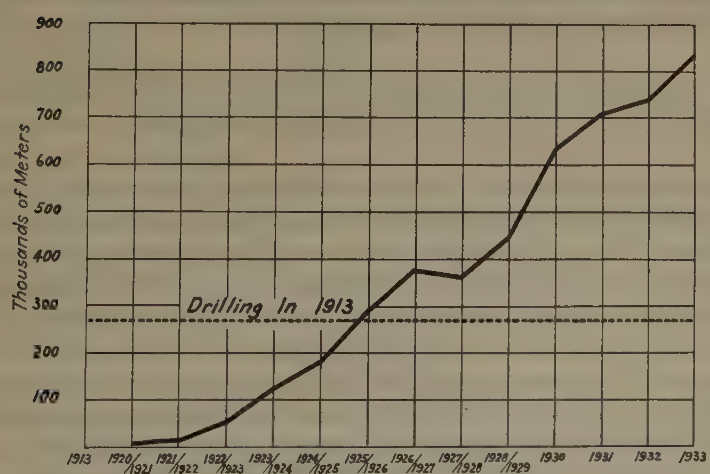

Fig. 7.—Oil-well drilling, U.S.S.R.

The U.S.S.R. is planning to solve its problem of deep drilling mainly by the use of the turbo-drill. Turbo-drilling eliminates many causes of stoppage inherent in rotary drilling, particularly at great depth. Tests of the turbo-drill performed in 1933 at 1000 to 2000 m. proved the superiority of the turbo-drill over the rotary rig. Turbo-drilling, up to the present time, has comprised a small percentage of the total drilling, amounting only to 2 per cent. But during all these years persistent work has been carried on with the view of perfecting the turbo-drill and eliminating its defects.

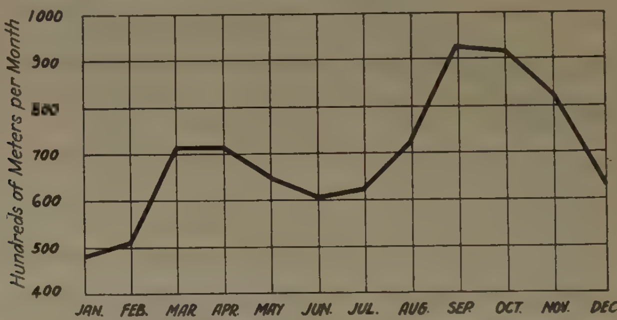

FIG. 8.—OIL-WELL DRILLING IN 1933, U.S.S.R.

The results of such work performed in 1933 (including the design of a multistage turbo-drill) led us to believe that in the near future the turbo-drill will find application, not only in deep drilling, but in drilling wells of average depths up to 1000 meters. One of the aims of the second Five Year Plan is to have this tool perfected and to introduce its wide application. The following figures show the decided increase in speed of turbo drilling for the best wells completed:

	1927–28	1928–29	1929–30	1931	1932	1933
Speed in turbo-drilling, meters per rig-month	47	63	102	125	160	262

Considerable attention has been paid during the last two years to the mud fluid. In this respect, the wide American experience was of great assistance to us. A number of tests were performed by the scientific institutes of the oil industry. Watching the quality of the mud fluid, observing the changes taking place in it, the organization of mud service and in many cases the organization of mud plants, were mandatory for all oil regions. The work performed during the last few years makes it possible to overcome the difficulties connected with deep-well drilling.

Starting with 1929, great efforts were made to overcome the crooked holes resulting then from the rotary drilling. At the present time the overcoming of these defects does not present any difficulties. Considerable help was rendered by the use of automatic feed of the bit, partic-

ularly by the automatic drill developed by Professor Skvorzoff, which found wide application in the U.S.S.R. oil fields. In automatic drilling the deviation does not exceed 0.5° per 100 m., and in many cases is considerably less. In turbo-drilling of wells 1900 m. deep the deflection of the bit does not exceed 0.1° per 100 meters.

In general there is a tendency at the present time to make the process of drilling more automatic. Work is being done to facilitate the control of drilling to replace manual operations by electric, pneumatic and hydraulic methods and to introduce distant control. Electrification made possible the introduction of the dispatcher system of group drilling control from a centralized point, which facilitates the management and control of drilling operations.

A system of group operation control has been devised by Soviet Engineer Goroyan. The control is effected by a combination of measuring instruments and light signals, which record the state of various operations of drilling; i. e., lowering and lifting of the drill, rates of feed and pressure, specific gravity of the mud fluid, performance of the slush pump, etc. At present a dispatcher system is being installed in the Baku region of the Stalin group for directing the drilling operations of 25 wells. Plans are being developed for the actual control of the technological process of the drilling. Attempts are being made to introduce the principles of television.

The facing of drilling tools with hard alloys in accordance with American practice was introduced in the Soviet Union in 1929 and has gained wide usage. At present the facing of all tools is being done with alloys of Soviet make: The Powder *Vokar* and the solid *Pobedit.*

Rotary disk bits and cutters are used widely, particularly in turbo-drilling, as well as core drills, which are satisfactorily manufactured at present in U.S.S.R.

In addition to the improved methods of securing samples by means of modern core drilling, electrologging, which speeds up the process of drilling, is also in wide use.

On the basis of A.P.I. practice and the work done by the scientific research institutes of U.S.S.R. considerable headway was made in simplifying well construction and in improving the material used for casings.

Improvements can also be recorded in ocean drilling on the shores of the Caspian Sea.

Production

Following nationalization the methods of operation underwent drastic changes. The reconstruction period brought about the replacement of old, unsatisfactory methods (bailing, open gushers) by modern methods of exploitation (deep pumping, gas-lift, control of gushers) based on complete electrification of all oil fields.

Some gushers still are not under control (Lok-Batam, Neftedag), but generally speaking the U.S.S.R. has mastered the art of gusher control. In a number of oil fields with high gas pressure open gushers are unknown (Maikop, Kola, Surakhani). Various types of equipment for high-pressure gushers are being manufactured in Soviet plants.

As a rule the gushers are operated through piping, the selection of which is done in accordance with methods developed by Soviet specialists. The use of the gas-lift method of production is rapidly increasing and replacing the air-lift. The method of centralized gas distribution between wells is used. The system of automatic gas distribution is being adopted. The Saunders method is generally accepted. The design of displacement pumps was developed and is being introduced. The gas is drawn off and is used in gasoline production. However, the losses in gas have not as yet been completely eliminated.

The establishing of modern and efficient methods of operation is still hindered by the inadequate supply of measuring apparatus.

The majority of wells (up to 80 per cent) are equipped with the ordinary types of plunger pumps, but recently more modern types of equipment have been introduced. Long-stroke and low-speed pumping is being intensively introduced. Great importance is placed on group drives.

The introduction of automatic operation from a central dispatcher's point has taken place recently. At present a central point is being erected for the control of 60 wells in the Ordzonikidze group (Surakhani).

The study and adoption of American methods and practice have been an important factor in the development of the U.S.S.R. methods of production. The Soviet engineer follows the development of American oil-production technique with intense interest, and tries to adapt to Soviet conditions the most promising innovations.

Research work is carried on with a view to ascertaining the possibilities of secondary oil extraction. Preparatory plans have been drawn for reclaiming by means of gas and water the residuary oil in the strata. An experimental advance heading is being cut in Grozny with the view of studying the possibilities of mining operations, and plans have been worked out for an experimental mine in the upper strata of Old Grozny. During the last year, plans have been worked out whereby the oil remaining in the stratum was to be displaced by hot gases obtained by burning and partially evaporating part of the oil. This method extracts practically all oil left in the stratum. This experiment is being carried out on a commercial scale at Maikop.

The production problems outlined for the near future are:

1. Complete automatic operation.

2. Filling the required needs in measuring and controlling equipment for the purpose of raising the production to a greater efficiency.

3. Improving and enlarging the equipment for deep drilling.

Refining Industry

The development of the refining industry in U.S.S.R. is proceeding in accordance with the growing domestic demands, the technical changes in the basic industries of the country, the change in the character of the required finished oil products, the growth of crude-oil production and the change in the quality of the raw material. This process proceeds constantly in the direction of abolishing the antiquated methods of refining, so characteristic of the prerevolutionary era.

With the beginning of the reconstruction period efforts had to be concentrated on the refining of the ever-growing output of crude oil. In addition, the rebuilding of the refining industry proceeded along the lines of maximum output of gasoline-ligroin-kerosene-lubricant fractions; of increased variety of final products; of improved fractional and chemical characteristics by the employment of modern refinery and chemical methods (cracking) and equipment.

In the first Five Year Plan, particularly in the last three years, great progress was made in all phases of the refining industry. In 1932 methods that cut deeply into the crude oil were used for refining 95 per cent of the country's output. In 1933 the percentage dropped to 86.3 per cent, owing to the lagging of production in the Grozny region.

The continuous growth of the basic products of the refining industry is shown in Table 8.

Table 8.—*Growth of Basic Products in Russia*

Product	1913	1928–29	1930	1931	1932	1933
Gasoline and ligroin	3.6	11.1	11.7	13.4	13.8	13.9
Kerosene	26.6	21.2	19.8	19.4	17.6	20.9
Lubricating oils	5.9	3.4	3.0	3.3	3.4	6.1
Dark products	60.7	62.5	62.0	61.0	62.1	55.3

The table shows clearly the growing intensity of refining and the increasing output of gasoline-ligroin and lubricating oils. This progress is particularly notable when the change in the character of the crude oils is taken into consideration. During the period 1928–29 to 1932, a large quantity of heavy crudes was subjected to refining. As an example, the refining operations of the Azneft region may be cited, where the refining of oils of low gasoline-ligroin content grew from 3 per cent in 1928–29 to 28 per cent in 1932. The rise in production of the basic products is shown in Table 9.

The production of all oil products went up sharply. As compared with the pre-war period the production of gasoline-ligroin increased thirteenfold, kerosene 2.5 times and lubricating oils 3.3. Cracked gaso-

TABLE 9.—*Production of Basic Products, U.S.S.R.*
Thousands of Metric Tons

Product	1913	1928–29	1931	1932	1933
Gasoline and ligroin	204	1204	2756	2881	2655
Cracked gasoline		3.2	406	593	679
Kerosene	1521	2319	3861	3824	3852
Lubricating oils	337	372	652	680	1127

line appeared in considerable quantities and in 1933 made up 25.6 per cent of all the gasoline-ligroin fraction. During the course of the first Five Year Plan alone the production of gasoline and kerosene doubled and lubricating oils tripled. In addition to the increase in production there was also a notable improvement in quality.

In 1932 the quantity of straight-run heavy gasoline produced was 760,000 metric tons, in 1933 it was only 370,000 tons. The lowering of the end point from 200° to 175°–185° C. improved the quality of the product. The total yield of gasoline did not drop, because of the development of the cracking process.

At the end of 1932 and during 1933 the end point for kerosene was lowered from 315°–340° C. to 290°–315° C. The yield of kerosene grew from 17.6 to 20.9 per cent, which was due entirely to the improvements in the technological process, the specialization of the plants according to the type of crude oil, reconstruction of the old equipment and the introduction of new modern tube stills.

Great qualitative and quantitative advances also took place in the production of lubricating oils. In addition to the general increase of the output from 680 thousand metric tons in 1932 to 1127 thousand metric tons in 1933, there was also a considerable increase of lubricants of high quality. In one year the production of cylinder oils increased from 106 to 140 thousand metric tons, motor oils from 218 to 400 thousand metric tons, bright-stock from 2.2 to 15 thousand metric tons, transformer oils from 2.6 to 28 thousand metric tons, and turbine oils from 2.9 to 5 thousand metric tons. The production of aviation lubricating oils increased 2.5 times.

Along with the improvements in production, changes were taking place in the purification methods of lubricating oil. Contact filtration, which started in Baku on a large scale in 1933, strengthened the basis of foreign trade in lubricating oils.

The production of paraffin wax in U.S.S.R. was started in 1926. The paraffin plant built (according to American practice) in Grozny was primarily meant to make the country independent of foreign paraffin imports. The plant was steadily enlarged to take care of the growing domestic demand and also for possible exports. Starting with an output

of 5000 metric tons in 1926, Grozneft increased the production to 19,000 metric tons in 1933. It produced a high-quality white paraffin, suitable for exports, which is continually growing. The exports of 1933 were double those of the first year. The improvements in equipment and methods of production introduced in the plant permit an estimate of production for 1934 of 35,000 metric tons.

There was also organized the production of ashless petroleum coke, which found extensive use in the aluminum industry.

During the first Five Year Plan a number of new byproduct industries were organized, producing ceresine, ozokerite, soap naphtha, greases and asphalt. All these products met with an increased demand throughout the country. Asphalt, in view of the growing road building program, acquired the position of a basic product.

All of these advances are the result of the extensive building of new plants, reconstruction of the old ones, and the employment of modern methods and equipment selected in accordance with the best American practice and scientific research work in U.S.S.R.

The building of new refineries on a large scale started in 1928. Before that there was only the enlarging and improving of plants inherited from the prerevolutionary period; the construction of new plants was on a small scale and in accordance with the practice prevailing in the country at that time. Radical departure from the old methods and the building of plants on a large scale took place during the years 1928–1933.

After nationalization new refineries were built with a total capacity of more than 20 million tons of crude oil. Of these, three were shell stills (with a total capacity of 1420 thousand metric tons), and two primitive tube stills (with a capacity of 410 thousand metric tons). They were constructed in 1928. The rest of the plants were built later. As a result of this construction period, the refining industry of U.S.S.R., in which there were practically no tube stills until 1928, produced 50 per cent of its output in 1933 in modern refineries. A complete picture of the new construction is given in Table 10.

TABLE 10.—*New Construction in Oil Industry, U.S.S.R.*

Put into Operation	1925	1926	1927	1928	1929	1930	1931	1932	1933
Number of shell stills	1	1	1	2	5		1		
Crude capacity, 1,000 tons	480	720	220	1,240	3,220		400		
Total capacity of all plants built, 1,000 tons	480	1,200	1,420	2,660	5,880	5,880	6,280	6,280	6,280
Number of tube stills			2		8	9	6	3	1
Crude capacity, 1,000 tons			410		2,160	3,660	3,050	11,000	440
Total capacity of all plants built, 1,000 tons			410	410	2,570	6,230	9,280	10,380	10,820
Number of cracking installations					1	18	5		2
Crude capacity, 1,000 tons					60	1,850	680		300
Total capacity of all plants built, 1,000 tons					60	1,910	2,590	2,590	2,890

In addition to the completed installations mentioned, there are in process of construction eight cracking plants in Saratoff, four in Grozny and one in Khabarovsk. Their total capacity is estimated at 2 million tons per year.

From Table 10 the following conclusions can be drawn: (1) the intensive building of plants took place during the years 1928–32 and, (2) this construction was carried out along the lines of increased plant capacity. The average yearly capacity grew from year to year. In 1929 it was 270,000 tons; in 1930 it was 407,000 tons, and in 1931 it was 510,000 tons. In the year 1932–33 vacuum-tube stills were built and their capacity was smaller. The same policy was carried out in regard to cracking installations; in 1929 the average yearly capacity of an installation was 60,000 tons, in 1930 it was 103,000 tons, in 1931 it was 136,000, and in 1933 it was 150,000 tons.

Technical Changes in Process of Direct Distillation, Cracking and Production of Lubricating Oils

The inherited, prerevolutionary, old and worn equipment required extensive repairs and process improvements in order to increase the production and to better the quality of the final products.

In 1925 rectifying towers were installed on the shell stills. This made possible the increase of gasoline production. The drawing off of gasoline was done directly during the process of distillation. This eliminated the necessity for redistilling the large gasoline-kerosene fraction in vapor stills (vapor gasoline distillation) and also reduced the losses in production and lowered the cost.

A decided improvement in the process of distillation was made in Baku in 1927. On the basis of the laboratory materials and technical information gathered from other countries, Soviet engineers designed and built two tube stills. The first tube stills of Soviet construction had many defects, but possessed nevertheless many advantages as compared with the existing shell stills, in regard to their output of gasoline and other light products and also lower consumption of fuel, steam, electric power and water. The experience with the first tube stills decided the further course to pursue in the development of the refining industry. The first American tube still of the Graver type was constructed in Baku in 1929. Since then, during the years 1929 to 1932, there have been put in operation 13 American tube stills, purchased from Foster-Wheeler Co., Badger Co. and Alco. The installation of these stills solved the problem of increasing the percentage of light products. In Baku, where the quantity of gasoline from the shell stills had been 70 per cent of the potential, the production of gasoline rapidly increased to 90 per cent. In Grozny the percentage increased from 80 to 92–95 per cent. The quality of the ligroin and kerosene was also higher.

Baffle and bubble towers were introduced in the U.S.S.R. in 1929.

The construction and operation of the modern type of tube still indicated in which direction the reconstruction of the shell stills should proceed. It was clear that these stills must be provided with the most efficient equipment in the form of bubble towers and heat exchangers.

The first 12-shell still battery in Grozny was rebuilt with the assistance of the Winkler-Koch Co. The productivity of the installation went up 190 per cent. The gasoline yield increased from 80 to 90 per cent of the potential. The rebuilding of the rest of the shell stills in Grozny was accomplished by Soviet engineers. On the basis of the modern tube stills, most of the Baku refineries were reconstructed.

As a result of the building of new plants and reconstruction of the old ones the basic system of straight-run distillation underwent a change. In 1913 all the refining was done in batteries of shell stills; in 1928, 8 per cent of it was done in tube stills, in 1932, this went up to 47 per cent and in 1933 it was 52 per cent. It should be emphasized once more that the production and efficiency of the old installations has increased considerably.

Up to 1931 the production of lubricating oils was on a very low level. It was confined exclusively to distillation of fuel oils in shell stills. The treating of the lubricating oil distillates was accomplished in batch mixers with sulfuric acid. In 1931 there was a change to American high-vacuum tube stills (Badger, Foster, Alco) and to Soviet stills of the Pengi-Gurovitch type. A plant of the Max Miller type was also built for the production of bright stock.

As a result of all this construction, the entire system of production of lubricating oils underwent a decided change. However, the major portion of the shell stills for lubricating oils were reconstructed and their

TABLE 11.—*Refining of Lubricating Oils from Fuel Oils, U.S.S.R.*

	1913	1928	1932	1933
Total quantity of fuel oil refined, 1000 tons	1130	1240	2675	3227
In shell stills, per cent	100	100	58	44
In tube stills, per cent			42	56

present efficiency is much higher than before. The reconstruction proceeded mainly in the direction of equipping them with head tube stills, for the purpose of feeding the shell stills with preheated fuel oil. This method increases the output of the installation and improves the fractionating of the lubricating oils. Also a new method of distillation was used, based on the Stratford principle with the recirculation of the fuel oil in the still (plant No. 6 in Baku). This method considerably raised the output of the shell stills and improved the quality of the final product. It is planned, during the second Five Year Plan, to continue the construction of

high-vacuum tube stills and to use some new treating methods (selective methods, redistillation).

The reconstruction of the refining industry was accompanied by improvements in the technical and economical performance of the plants. In addition to the improvement in the quality of the final product and more efficient utilization of the raw material, there was also better organization of labor and lower costs of production in the largest trusts. In Azneft the cost of production of gasoline dropped 16 per cent during the period 1928–1933; kerosene, 20 per cent; machine oil, 46 per cent and motor oils, 39 per cent.

The main factors in lowering the production costs were the decrease of production losses, reduction in fuel and steam consumption, lowering of labor costs (by increased productivity of labor) and decrease of rate of amortization per unit of production (by higher efficiency of plants).

Transportation and Storage

Transportation occupies an important place in the petroleum industry everywhere. It is of vital importance in U.S.S.R., where at present the main oil resources of Baku and Grozny are far from the main centers of consumption of the oil products.

The progress in production and refining, the change in the character of the domestic market, the increase in export—all these factors brought about an acute need for better transportation and storage facilities. The new conditions dictated also the necessity for new coordination of the railroad, water and pipe line types of transportation, as the prerevolutionary means of transportation were inadequate and technically inefficient. The problems of oil transportation were solved to a great extent in the period 1928–1933. The country's new planned transportation system includes the increasing of the carrying capacity of the old lines and the adding of new means of transportation, railroad, water and pipe lines. This was made necessary by the increased demands of the domestic market and exports. The increased use of the various forms of transportation and their relative importance are shown in Table 12.

Table 12.—*Transportation of Oil, U.S.S.R.*
Thousands of Tons

Type of Transportation	1913	1928	1929	1930	1931	1932	1933[a]
Rail	5,800	8,720	10,216	13,197	15,069	17,000	16,900
Sea transportation between Soviet ports[b]	5,264	5,392	6,049	7,896	8,952	9,910	10,008
Inland waterways	5,384	4,933	5,341	5,379	7,560	7,080	6,395
Pipe lines	370	825	1,548	2,817	3,293	4,350	5,400

[a] The figures for 1933 are estimated. [b] Sea transportation does not include export.

Table 12 clearly shows the decided changes in the means of transportation. In 1913 the transport by pipe lines amounted only to the insignificant figure of 370,000 tons, the total length of the trunk lines was 1242 km. In 1933 the total length of lines increased by 2000 km. and the total throughput was 14.5 times that of 1913, comprising 14 per cent of the total quantity of oil products transported.

The character of the oil transportation underwent a change in the years 1928–1933 also. Transportation by inland waterways dropped from 24.8 to 16.5 per cent with the corresponding increase of the throughput of the pipe lines from 4.1 to 14.0 per cent. The percentage of rail and sea transportation remain almost constant: By rail, 43.9 per cent in 1928 and 43.7 per cent in 1933; by sea, 27.2 per cent in 1928 and 25.8 per cent in 1933. The absolute increase in rail transportation was due to the increased domestic consumption of light products and to increased delivery of oil products to remote regions, particularly to the eastern sections of the country, where the development of big industrial and agricultural enterprises was taking place. The failure of the Volga to fulfil its assigned share of transportation placed additional burdens on the railroads.

Mainly for that reason, the transportation of oil products grew to a larger share in the general railroad transportation of the U.S.S.R., from 6.8 per cent in 1928 to 8.9 per cent in 1933. A considerable contributing factor was the increase of the average distance of transportation of the oil products. The creation of new consuming centers increased this index from 748 km. in 1928–29 to 935 km. in 1933.

The sharp increase in rail transportation caused a corresponding need of building additional rolling stock and of wide improvement in the railroad system. The most important step taken in this direction was the building of a large quantity of eight-wheel railroad tank cars with a capacity of 45 to 50 metric tons instead of the commonly used four-wheel tank cars with a capacity of 15 to 25 tons each. Considerable improvements resulted also from the improved method of loading and unloading tank cars and from better routing (direct full train-load shipments to far points—Moscow, Leningrad and others). Because of the improved devices for filling and emptying tank cars the average time for such operations was reduced in 1932 to 4 hr., as against 7 hr. in 1931. To the stock of tank cars were added new types, equipped with heating devices for the transportation of viscous products and hermetically tight for volatile products.

The building of large tankers, both seagoing and for inland waterways, increased the transportation on the Black Sea fivefold as compared with 1928, and provided a commercial fleet for almost the entire U.S.S.R. coasting trade.

The Soviet shipbuilding plants constructed seven tankers of large capacity, of which the following deserve particular mention: "Soyuz Vodnikov" and "Soyuz Metallistov," of 10,000 tons each; "Embaneft," 9600 tons; "Soyus Gornorabochikh," 9800 tons, and "Mossoviet," 8500 tons.

The Caspian Sea oil fleet consists at present of 66 vessels with a total capacity of 130,000 tons. During the years 1928–33 six new vessels with oil-burning engines, each with a capacity of 7500 tons, were launched. These vessels have a draft of 22 to 23 ft. and a speed of 11 to 12 miles per hour, as compared with 8 to 9-mile speed of the old vessels. The new ships make 50 voyages and transport from 350 to 375 thousand tons of oil products per season.

The total length of the trunk pipe lines in 1913 was 1242 km. Of these the most important was the 8-in. kerosene pipe line between Baku and Batoum (883 km.). It was used only to 35 to 40 per cent of its capacity, because of the falling exports of kerosene. The rest of the lines, Grozny-Makhatch-Kala (161 km.), Maikop-Krasnodar (108 km.), and Emba-Kakush (90 km.), were of minor importance. The throughput of all these lines amounted, as mentioned before, to the insignificant figure of 370,000 tons.

The laying of pipe lines in U.S.S.R. started in 1927 with the construction of the Grozny-Touapse (618 km.) and Baku-Batoum (822 km.) lines. The first line was completed and put in operation at the end of 1928. The second, at the end of 1929. The old kerosene pipe line was used for pumping crude oil. The two Baku pipe lines deliver yearly to the refinery plants in Batoum 2,500,000 tons of crude.

In 1930 the Grozny-Touapse pipe line, with a throughput capacity of 1,000,000 tons of crude, was enlarged to a capacity of 1,650,000 tons by constructing four additional stations and by laying 27 km. of parallel piping. In addition, 8 km. of piping was laid to include 330,000 tons of Maikop crude in the flow.

For the purpose of taking care of the needs of the basic agricultural regions of U.S.S.R., a 12-in. pipe line 418 km. long was laid between Armavir and Trudovaia in April, 1932, for pumping oil products. The construction of this line took only one year. It was designed to distribute part of its load (tractor fuel) on the way and therefore its throughput is not uniform. As far as Rostov, the throughput is 1,650,000 tons (kerosene) and to Trudovaia, 1,300,000 tons.

It is planned to connect by pipe line Grozny and Armavir (395 km.) in the near future.

In March, 1932, the construction of a 12-in. pipe line, Guriev-Orsk (707 km.), for the purpose of pumping Emba crude, was begun. By the beginning of this year 278 km. of piping had been laid out and 250 km. welded. Two stations had been completed. The work is being carried

out under exceptionally difficult conditions, in a dry and desert land, in the absence of roads, in extreme continental climate and in unfavorable soil. It is planned that one line with a throughput of 500,000 tons per year will be completed in the beginning of 1935 and another of 1,500,000 tons capacity in the beginning of 1936.

A small pipe line was constructed on Sakhalin Island (32 km.).

Modern methods of construction were employed in the building of all pipe lines. Electric welding was first applied in 1927 in the Grozny-Touapse pipe line. In the building of the Guriev-Orsk pipe line the welding was divided equally between gas and electric methods.

At present there is in the petroleum industry of U.S.S.R. a well established organization, "Nefteprovodstroi," equipped for modern pipe line building.

In the years 1928–32 the number of storage centers of the Soyuzneftetorg increased from 836 to 1086, or 30 per cent. This growth was the result of the increasing turnover in oil products. The increase in the number of storage centers was accompanied by the enlarging of their capacity. On Jan. 1, 1928, the storage capacity of Soyuzneftetorg was 4,793,000 tons (water) and on Jan. 1, 1933, the same comprised 6,489,000 tons, an increase of 35 per cent. Characteristic of the intensive development of storage facilities during that period is the building of storage places in outlying regions of the country (Kazakstan, Middle Asia and others).

Extensive work was done in consolidating the storage facilities and in uniting the separate small units. The pumping facilities and the power-generating plants were increased, resulting in more frequent turnover of the storage capacity. If we should compare the growth of the oil products delivered to the domestic markets with the growth of the storage facilities, we should find the first curve much higher than the second, which proves that part of the increased consumption of the oil products was taken care of by the increased efficiency of the old storage system.

It is of interest also to point out the work done in replacing the heating coils in reservoirs by a special heating arrangement, which resulted in a great saving in fuel (2 to 3 times) and metal (90 per cent).

Manufacture of Machinery Equipment for Petroleum Industry

In carrying out the technical reconstruction of all branches of the industry, in adapting the best American technique and creating its own designs, the U.S.S.R. was confronted with the necessity for organizing powerful plants for the production of machinery and equipment for the petroleum industry.

The building of oil machinery started in 1923 in the shops of Sormovo, Kalumni and Briansk plants. During the first years the work was carried out on a small scale and mostly for supplying the oil fields with

minor items of equipment. The important machines and rigs necessary for drilling and production came from abroad.

Large production of oil equipment started in 1928–29; that is, at the beginning of the first Five Year Plan. In that year the total output of machinery was valued at 9,260,000 roubles. In 1929 the machine-building plants of Azneft and Grozneft were re-equipped (with modern machinery) and enlarged. During the last few years, large shops were built for the production of equipment for oil refineries. A number of shops in pipe plants were assigned to the manufacture of supplies needed to meet the growing demand of the oil industry.

In 1928–29 the restriction of importation of oil field equipment started, because of increased Soviet production.

TABLE 13.—*Production and Import of Oil Field Equipment*

	1930	1931	1932	1933
Produced in U.S.S.R., 1,000 roubles	14,083	17,661	19,133	27,000
Imports, 1,000 roubles	5,200	4,500	640	300
Import in relation to total, per cent	26.9	19.4	3.2	1.1

During the years 1929–1933 the Soviet machine-building industry familiarized itself with almost the entire oil-field equipment and machinery used in the U.S.A. It mastered the production of more than 100 types of equipment previously imported from abroad. Of these the main items are: four-speed hoists with corresponding rotors for rotary drilling; closed-type rotors; crown blocks 130T.; swivels 130T; pulley crowns 130T; lifting hooks 130T; cementing units; roller drills and bits; slush pumps (7¼ by 16 for pressures up to 100 atmospheres); two-motor reductors; blow out "preventers"; high-pressure gusher equipment; gas-lift compressors with a capacity of 13 cu. m. at 45 atm. pressure.

The production of special oil engines of 210 hp. and of three-phase, 440-volt, 225-hp. electric motors is planned for 1934.

The growth of pipe manufacture for drilling, production and transportation purposes deserves particular attention. By 1933 the Soviet plants were in a position to manufacture the complete assortment of pipes used in the oil industry (except pipes for cracking and tube stills). However, the pipe plants in U.S.S.R. do not fully meet all the needs of the oil industry. The U.S.S.R. oil industry requires large quantities of piping of high quality; these requirements have been particularly large during the last years, because of the necessity of solving the deep-drilling problems, the increase in drilling meterage and the growth of production. Large demands for piping are also made by the refinery industry and by the pipe lines. It is necessary, therefore, to import some pipe from abroad. Table 14 shows how the demand for pipe was met (in tons).

TABLE 14.—*Production and Import of Pipe for Pipe Lines, U.S.S.R.*

	1930	1931	1932	1933
Domestic production, tons	78,700	111,200	86,600	103,200
Imports, tons	5,900	24,200	5,300	18,900
Imports in relation to total, per cent	6.9	17.8	6.1	15.4

Up to 1930 the building of new refineries depended almost entirely on imported materials. The cracking plants of Vickers, Jenkins, Winkler-Koch; the tube stills of Pinch, Borman, Wilke, Foster, Badger, Alco and Graver were imported almost in their entirety, including the smallest details.

The production of the basic equipment for cracking plants and tube stills in U.S.S.R. started in 1930. During the years 1930–33 there was manufactured equipment for 17 cracking plants, three tube stills, etc. at a total cost of 20 million roubles.

The planned production of equipment for 1934 amounts to 18 million roubles.

At the present time the Soviet machine-building industry is in position to furnish the apparatus and structures for the following installations: cracking plants, atmosphere-vacuum tube stills, vacuum tube stills, tube stills for recycle distillation in cracking, plants for continuous treating of gasoline and kerosene, carbon-black plants and gas-absorption plants.

In 1934 there will begin the standardized production of: vapor-distillate heat exchangers for cracking plants, recuperators for cracking plants, return bends for cracking and tube-still units, high-pressure accessories for them and measuring and control apparatus.

With the Soviet plants manufacturing apparatus and equipment for refineries, the import of these items took a decided drop. Taking 1930 import figures as 100 per cent (10,800,000 roubles), the imports of the following years were:

Year	Per Cent	Roubles
1931	63.9	6,900,000
1932	19.4	2,100,000
1933	9.2	1,000,000

The machine building for the oil industry during the second Five-Year Plan faces a number of new problems, in connection with the development of new types of equipment for closed drilling.

In tube-rolling mills it is necessary to arrange for mass production of piping for cracking and tube-still installations. For refinery plants it is necessary to organize the manufacture of the apparatus for vapor-phase cracking, reforming installations, paraffin and lubricating oil treating plants (filter presses, crystallizers, mixers, etc.).

Labor and Its Organization

The main underlying factor that caused the rapid growth and technical reconstruction of all branches of the Soviet economy is the principally different (as compared with other countries) social position of the working class in the U.S.S.R. Their attitude toward the means of production and the whole economy, as to something belonging to themselves, the consciousness of the fact that they work exclusively for themselves and their state caused an unheard of enthusiasm, brought to life new forms of labor, socialist competition and shock work, and made labor in the Soviet land a thing of honor, valor and heroism.

Labor is looked upon in U.S.S.R. as the main productive force of society and therefore to the problems of labor are given utmost attention along with the problem of creating a material-technical basis for socialist construction.

In this respect the policy of the Soviet Government is toward a systematic improvement of the material well-being of the workers, basing these improvements on the technical reconstruction of the country and on increased efficiency of labor.

During the first Five Year Plan the main steps taken in the direction of improving the material position of the worker were the gradual introduction in the oil industry of the seven-hour day with increased wages and complete elimination of unemployment.

The growth in production and refining necessitated the employment of a considerably larger number of workers and specialists, though the rate of increase of labor in this industry was less than the rate of increase of production. This is due to technical advances and to the increased efficiency of labor.

Table 15.—*Number of Workers in the Oil Industry, U.S.S.R.*

	1928–29	1932	1933
Number of workers	63,443	98,941	98,796
Percentage of 1928–29 total labor	100	156	155.9
Growth of drilling, 1,000 meters	446	743	838
Percentage of 1928–29 drilling	100	166.6	188.0
Increase in production, 1000 tons	13.7	21.3	21.5
Percentage of 1928–29 production	100	155.5	157.0
Production of light products and lubricating oils, 1,000 tons	3,895	7,385	7,644
Percentage of 1928–29 production	100	189	196.5

As mentioned before the quality of the final products was greatly improved at the same time.

The introduction of modern equipment created the problem of mastering its operation, which necessitated raising the standard of the

qualifications of the workers, and increased the importance of the engineers and technicians and of the trained groups. In order to solve this problem there were organized advanced technical schools, technical high schools and training schools. Efforts were also made to raise the qualifications of all the workers by technical instruction (various schools for advancing the qualifications of the workers, special lectures, popular technical literature, etc.).

As a result of these efforts, the work of the specialists became more productive and there was also an increase of the number of skilled workers from the ranks of unskilled labor, accompanied by a general rise of the technical and cultural levels of all the workers.

TABLE 16.—*Change of Complex of Workers in Oil Industry, U.S.S.R.*

Year	Workers	Specialists	Clerical
1928–29	52,915	4,500	6,028
1932	78,649	9,313	10,979
1933	75,562	9,950	9,384

Table 16 shows that while the number of workers increased from 1928–29 to 1933 by 50 per cent, the number of specialists increased at the same time 121.1 per cent, with the result that their percentage in relation to the workers increased from 8.5 per cent in 1928–29 to 11.8 per cent in 1932, and to 12.5 per cent in 1933.

There was also an increase in skilled workers in relation to the total number of workers. In Azneft the percentage grew from 28.8 in 1928 to 36.4 in 1933, while the total number of skilled workers increased 1.5 times.

Placing great importance on the increase of labor efficiency in all branches of the country's economy, the U.S.S.R. is reconstructing its technical foundation and directing its efforts toward the mechanization of large labor-consuming processes and such organizations of production as rapidly increase the efficiency of labor.

Six basic conditions govern the planning and organizing of labor in all branches of the economy, laid down by J. V. Stalin at the convention of heads of industries in 1921:

1. Elimination of unemployment and decided improvement of living conditions of the peasant in connection with the collectivization of agriculture require that *the hiring of labor should be organized in conformity with agreements with collective farms and that work should be mechanized.*

2. The immense scale of production and the use of complicated machinery require *elimination of high labor turnover by means of adequate arrangement of the wage scale,* which should stimulate the increase of efficiency of labor and enhance its qualifications, and *improvement of the living conditions of the workers.*

3. *It is necessary to eliminate the state of irresponsibility for the condition of the equipment* and to organize labor so that it should carry responsibility for its share of production.

4. The rapid growth of industry in all parts of the Union requires that the *working class of U.S.S.R. should possess its own production-engineering forces.*

5. *The favorable change in the attitude of the engineer of the old school* toward the Soviet Government, caused by the success of the socialist construction, merits also a *change in the attitude of the Soviet workers* toward these engineers, *paying more attention to them and to their needs, a less hesitating policy in allowing them to participate in our work.*

6. The problem of increasing the accumulation of reserves in industries of the country for further reconstruction of the economy requires the mobilization of the country's resources, adoption of and adherence to a system of economic operation for all enterprises.

During the first Five Year Plan there was a decided improvement in the cultural and material conditions of the workers in the oil industry. We have pointed out before the seven-hour day with increased wages. In addition to that, housing of the workers has improved decidedly. In the oil regions (Baku, Grozny, Touapse, Maikop, Emba and others) socialist towns and workers' villages were built, having excellent, well arranged houses. Such are the villages Mantin and Rasin (Baku), the villages of the Nov-Grozny region, the villages in the neighborhood of the refineries of Touapse and others.

In order that these accomplishments may be rightly appraised, it is necessary to point out that the housing conditions of the oil workers of prerevolutionary Russia were extremely poor.

In addition to house building, workers' clubhouses, palaces of culture, dining rooms, factory kitchens, hospitals, etc., were built.

There was also a decided improvement in ways of communication. Street cars, electric and horse-drawn, railroads, buses and the building of improved paved roads connected the oil fields with the villages. Toward the same end is directed the introduction in the oil industry of a system of wages that raises the efficiency of the workers and their qualifications. In the oil field, the piece-work and bonus system is used and in the refinery industry the piecework progressive scale is mostly used.

The compensation of skilled labor is considerably higher than that of unskilled, in accordance with the seven-category wage schedule by which the ratio of compensation of class 1 to class 7 is 1:3.1.

The organization of cost-accounting units, the system of work orders for each shift of workers and specialists, the elimination of the functional system of management, do away with the anonymity of the worker and create a responsibility in each worker for the job entrusted to him.

The graduates of the three oil colleges (Moscow, Grozny and Baku) that fill yearly the ranks of the young specialists and also the favorable attitude toward the old-time specialist serve to provide the industry with a skilled, reliable, technical management.

And, finally, the institution of cost accounting in all the links of the industry, from the general management to each workers' brigade, lead to economical operation and to the creation of reserves.

The plans for the second Five Year Plan call for a still higher rate of growth of the oil industry and for further advances in its technical foundation.

This requires still greater mastery of the new technique of oil fields and refineries. The problem is closely connected with the plans for increased efficiency of labor and reduced cost of production. The fulfilment of these plans requires the preparation of new trained *cadres* of workers and specialists and a systematic rise in their qualifications. We must devote attention also to the organization of labor and the betterment of the material well-being of the workers of the oil industry, together with the general advancement of the economy of the U.S.S.R.

Scientific Research Work

The reconstruction of the foundation on which the oil industry rests, which proceeded at such rapid pace, and which accounts for the qualitative and quantitative accomplishments, would have been impossible without scientific research work on a large scale and without stimulating the inventive genius of the practical workers in the industry.

At present there are in the petroleum industry of the U.S.S.R. four scientific research institutes and scores of large plant and oil-field laboratories, which are closely connected in their work with the oil production. Of the four institutes three (State Institute for Oil Research in Moscow, Grozny and Azerbaidjan Institutes) are of a complex nature and cover the research work in the various problems of oil-field and plant construction, in the chemistry of oil, in pipe line application, and so forth. The fourth institute (Geological Exploration Institute of Moscow) specializes in geology and oil prospecting.

There is no overlapping of work in the institutes and plant laboratories because of the centralized direction of their programs and the absence of trade secrets, making it possible for the discoveries in any one of the institutes and laboratories to be made known to all the scientific research organizations of the industry.

As a consequence of such a policy in directing the scientific research work of the country, and of the importance placed on such work in U.S.S.R., it was made possible not only to utilize the experience and knowledge of foreign technique but to apply, in growing numbers, the designs of the Union's own specialists.

These include the various geophysical devices (variometers, seismographs and others), turbo-drill of Kapeliushnikov, the automatic rig of Skvorzov, the cracking systems of Shukhov-Kapeliushnikov, Dubrov and others.

The year 1933 was particularly productive in scientific research work, which is due to the fact that the young scientific research organizations, established a few years after the nationalization, grew up to the extent of being able to solve large theoretical and practical problems.

In the sphere of geological exploration there was introduced, in addition to the further study of method of application and improvements of the geophysical apparatus, electrical logging and electroexploration, a new method of gas exploration, which consists in sampling and analyzing the air over the ground being surveyed. The application of this method in the oil fields of Kala, in the Baku region, gave splendid results, having confirmed the presence of exudation of oil gases through the whole depth of the cap soil covering the oil strata, and the possibility of using the gas method for securing direct and reliable information as to the presence or absence of gas and oil in the ground.

Of the purely scientific research particular attention should be drawn to the work in microbiology of oil, which represents a great contribution to the science of the genesis of oil.

Considerable experimental work was carried out in the field of production and drilling. Of particular importance to the further development of the Soviet oil industry is considered the work of redesigning the Kapeliushnikov turbo-drill, being done by the State Institute of Oil Research.

The redesign is based on the idea of distributing the total pressure of the mud fluid among the stages of a multistage turbine. The redesigned drill possesses much higher mechanical efficiency and doubled power, while having the same general dimensions. The multistage turbines tend also to eliminate the shortcomings of the present design; namely, the quick wearing of the blades due to their very high speed. The tests that are being carried out with new turbo-drills show gratifying results. On the basis of this success it is planned to use the method of turbo-drilling in the first line of very deep drilling. The Azerbaidjan Institute for Oil Research has completed a number of experimental tests with various alloys for tool facing and with the methods of their application. This work has already produced great practical results. Lately there are being carried out on a large scale experiments with the dispatcher system of drilling control.

A great deal of attention is devoted also to the improvement of production methods with a view toward planned exploitation of all oil-bearing strata on the basis of the latest scientific achievements.

In the summer of 1933 there was a convention of the All-Union Scientific Technical Society at Baku, where the results of the research in that field were reported and the experience in manufacturing practice was summarized.

Of greatest interest is the work performed by the State Institute for Oil Research, tending to ascertain the possibilities of secondary oil extraction by means of evaporation and gasification. Experiments on a commercial scale will be carried out in Maikop oil fields in the spring of 1934, which will show the possibilities of the method and scale of practical application. The laboratory experiments gave splendid results, which justify expectations of the possibility of practical application of the method and its successful performance in the field.

In the province of refining and utilization of oil, research work is carried on in all three complex institutes. There an intensive study of the chemical and fractional properties of oil is going on.

On the basis of these researches constructional and technological improvements are being introduced in gasoline, kerosene and lubricating-oil production and a whole series of new products is being developed.

Of utmost interest is the work directed toward the creation of systems of vapor and liquid-phase cracking and toward the hydrogenation of crude oils by means of various catalysts carried out in experimental continuous-process installations, which greatly contributed to the reduction of process pressures and temperatures. Considerable work was done in research of methods of treatment of the various oil products, of which the process of treating gasoline by means of solid chlorinated zinc deserves special mention, as also the preliminary alkaline treatment of crude oils already employed in some of the plants. A large amount of interesting research work is being conducted in the chemistry and technology of crude oil. The Grozny Institute was successfully conducting research in synthetic oils. The large demand for higher types of fuel, created by autotransportation and tractors placed before the scientific research institutes the problem of standardizing the oil products.

In connection with the recent success in building diesel engines, the State Institute for Oil Research is carrying on experiments for ascertaining the most suitable type of fuel and the methods of production of the latter. The institutes are also occupied with the problems of transportation, storage and distribution of the oil products with the view toward reconstruction of all these branches of the oil industry.

It is characteristic of all these research institutes, which are actively supported by the government and the people, that their work is acquiring greater scientific value and import, recognized not only in U.S.S.R. but also abroad. Of great importance is the work performed during the last few years, particularly in 1933.

At the same time the institutes are gradually enlarging their equipment and apparatus and increasing their personnel. The uniting of science with industrial practice resulted in productive scientific research work and its quick absorbtion by the industry.

Conclusion

Having discovered a number of new rich oil reserves, being better equipped with knowledge of modern industrial methods and constantly improving the organization of its labor, the petroleum industry of U.S.S.R. has entered a new phase of high-speed development. The planned increase in the production of oil for 1934 is 36 per cent. At the end of the second Five Year Plan (in 1937) the production of crude oil (including gas) must reach 47 million tons. This will be accomplished by extensive exploitation of the petroliferous lands, by flexible and rapid development of new reserves and by intensive use of new methods in further geological explorations. The process of refining must cut deeper into the crude oil and the higher utilization of high-quality crude oils by chemical methods must find wider application. For this purpose it is planned to build in different sections of the Soviet Union 16 new modern tube stills, 93 cracking units and many other types of equipment, adapted to the new methods of production. It is also planned to build 4000 km. of pipe lines for the transportation of crude and finished oil products. All this is required to satisfy the demand of the country which in 1937 alone will build 200,000 automobiles and 167,000 tractors, and which will have constructed during the Five Year Plan 210,000 km. of improved and paved roads, and have increased the total length of air lines 120,000 kilometers.

It is understood that the fulfilment of these plans is closely interwoven with the mastering of the newest technique in oil production, with the consequent improvement of the quality of the oil products, with higher efficiency of labor, and with the lowering of production costs of crude and finished products. The first line of attack is the problem of deep and super-deep drilling. This problem must be completely solved during the second Five Year Plan on the basis of Soviet and American methods.

As in the past, a great many problems will have to be solved by utilizing the broad American experience. But native scientific research, inventive and designing abilities will have to play an increasingly important part. In connection with this there is a greater necessity for equipping our whole system of scientific research institutions with large laboratories and plant models and with a highly qualified corps of workers.

Petroleum Development in Venezuela in 1933

By F. Hulsmeier,* Maracaibo, Venezuela

(New York Meeting, February, 1934)

The increase in drilling activities in Venezuela noted during the latter half of 1932 continued, and 132 wells were completed in 1933 as compared to only 60 completed during 1932. Notwithstanding these new wells, 114 of which were producers, and also the appreciable increase in artificial lifting installations during the year, Venezuelan production

Table 1.—*Petroleum Production and Exports, Venezuela,* 1933
(Barrels of 42 U. S. Gallons)

	Production	Rate Per Day	Exports	Rate Per Day
January–June	57,038,000	315,127	57,975,000	320,304
July–December	63,318,000	344,120	61,413,000	333,766
Total, 1933	120,356,000	329,742	119,388,000	327,090

Table 2.—*Summary of Production and Exports by Years, Venezuela*
(Barrels of 42 U. S. Gallons)

Year	Production	Exports	Year	Production	Exports
1917	226,000	57,000	1925	20,581,000	18,927,000
1918	367,000	144,000	1926	36,997,000	33,743,000
1919	259,000	14,000	1927	63,108,000	57,303,000
1920	526,000		1928	105,590,000	100,659,000
1921	1,498,000	998,000	1929	137,745,000	130,045,000
1922	3,394,000	1,813,000	1930	137,212,000	137,745,000
1923	3,741,000	3,344,000	1931	118,525,000	116,683,000
1924	9,147,000	8,554,000	1932	118,167,000	114,567,000
			1933	120,356,000	119,388,000
Total to date				877,439,000	843,984,000

was maintained at only a slightly higher level than in 1932, amounting to 120,356,000 bbl. in 1933 as compared to 118,167,000 bbl. in 1932. However, at the end of the year the daily average production of 358,-860 bbl. was 16 per cent higher than that at the end of 1932. Exports from Venezuela recorded an increase of approximately 4 per cent, totaling

* Venezuela Gulf Oil Co.

TABLE 3.—*Summary of Production in Venezuela during* 1933

Fields	Age, Years	Area Proven Acreage[a]	Oil Production: To End of 1933	Oil Production: During 1933	Oil Production: During 1932	Oil Production: Daily Average, November, 1933	Average Gravity of Oil, Deg. Bé.	Status of Productive Wells at End 1933: Flowing	Pumping	Air-gas Lift	Total Producing	Not Producing	Total
La Rosa	11	19,000	220,434,000	23,330,000	23,600,000	61,740	18–28	146	209	93	448	456	904
Punta Benitez	8	3,600	6,022,000	1,896,000	760,000	5,530	16–28	17	0	0	17	27	44
Tia Juana	6	4,000	29,000				15–17	0	0	0	0	10	10
Lagunillas	8	16,700	432,793,000	58,549,000	62,112,000	184,770	14–21	206	83	86	375	261	636
Bachaquero	4	3,700	36,000				12	0	0	0	0	3	3
Cumarebo	2	200	7,058,000	4,982,000	2,055,000	14,390	45–50	24	0	0	24	12	36
El Mene	11	900	18,157,000	889,000	1,169,000	2,280	37	2	44	51	97	3	100
El Mene de Acosta	5	100	679,000	94,000	116,000	210	41–45	0	20	0	20	4	24
Guanoco	9	30	1,718,000				10.5	0	0	0	0	15	15
Hombre Pintado	6	100	153,000	15,000	22,000	35	28	1	0	0	1	2	3
La Concepcion	9	1,000	14,176,000	2,165,000	2,173,000	6,120	35	9	56	4	69	32	101
La Paz	9	200	3,086,000	281,000	423,000	685	27.5	2	1	2	5	24	29
Las Palmas	6	40	165,000				34	0	0	0	0	8	8
Los Manueles	4	400	10,951,000	4,265,000	3,120,000	9,720	33	10	0	0	10	2	12
Media	3	50	1,714,000	802,000	639,000	1,050	44.5	6	0	1	7	1	8
Mene Grande	19	4,900	126,614,000	13,066,000	13,548,000	39,110	16.5 & 29.5	33	0	58	91	131	222
Quiriquire	7	6,500	16,078,000	6,698,000	4,969,000	22,820	17–19	33	5	0	38	19	57
Rio Tarra	12	800	16,786,000	3,324,000	3,384,000	10,400	33	10	9	0	19	46	65
Totumo	6	700	148,000		3,000		21	0	0	0	0	12	12
Other fields and wildcats													
Maracaibo Basin			402,000		74,000							13	13
State of Falcon			233,000									5	5
Eastern Venezuela			7,000									5	5
Totals		62,920	877,439,000	120,356,000	118,167,000	358,860		499	427	295	1,221	1,091	2,312

[a] Most fields not fully defined; these figures for comparative purposes only.

119,388,000 bbl. during 1933 as compared to 114,567,000 bbl. during 1932. Oil in storage in Venezuela decreased approximately 47 per cent, from 7,023,000 bbl. at the end of 1932 to about 3,693,000 bbl. at the end of 1933.

Table 1 shows production and exports and the average rate per day for the last six months of 1933 compared to the first six months; Table 2 shows production and exports by years from 1917 to 1933 inclusive; Table 3 shows a summary of production in Venezuela during 1933 by fields; and Table 4 shows a summary of drilling in Venezuela during 1933 by fields.

TABLE 4.—*Summary of Drilling Operations in Venezuela during* 1933

Fields	Wells Completed				Abandoned Producers	Average Depth of Wells Drilled during 1933	Active Drilling Operations at End of 1933	
	Total to End of 1933		During 1933					
	Prod.	Dry	Prod.	Dry			In Prod. Fields	Wild-cats
La Rosa	922	36	38	0	18	1693	1	
Punta Benitez	44	3	0	0	0		0	
Tia Juana	10	2	0	0	0		0	
Lagunillas	642	4	36	0	6	3053	3	
Bachaquero	3	0	0	0	0		0	
Cumarebo	36	5	16	5	0	1732	2	
El Mene	186	99	0	0	86		0	
El Mene de Acosta	41	39	1	1	17	1318	0	
Guanoco	16	6	0	0	1		0	
Hombre Pintado	3	2	0	0	0		0	
La Concepcion	101	1	2	0	0	3542	0	
La Paz	30	3	0	0	1		0	
Las Palmas	8	5	0	0	0		0	
Los Manueles	12	1	3	0	0	3997	1	
Media	11	11	3	8	3	3959	2	
Mene Grande	229	7	2	0	7	2734	2	
Quiriquire	57	6	9	1	0	2796	4	
Rio Tarra	65	13	2	0	0	3418	1	
Totumo	12	1	0	0	0		0	
Other fields and wildcats								
Maracaibo Basin	13	108	0	0	0			0
State of Falcon	5	55	0	2	0	5555		0
Eastern Venezuela	5	24	3	0	0	3202		3
Totals	2451	431	115	17	139	2550	16	3

FIELD DEVELOPMENTS, LAKE MARACAIBO BASIN

Bolivar Coastal Fields (Including La Rosa, Punta Benitez, Tia Juana, Lagunillas and Bachaquero—situated on the eastern shore of Lake Maracaibo in the District of Bolivar, State of Zulia).—Production from this group of fields amounted to 83,775,000 bbl., or 70 per cent of the total for Venezuela during 1933. This represented a decrease of 3 per

cent under the 1932 figure; however, at the end of 1933, the fields had a daily average production 24 per cent higher than at the end of 1932, this average being 252,040 bbl. as compared to 212,491 bbl. at the end of 1932. Of the total production obtained from these fields in 1933 approximately 6,000,000 bbl. was recovered from new wells completed during the year. The Tia Juana and Bachaquero wells remained closed in, but practically all other "closed in" producers were opened to production during the year. Table 5 shows the number of wells producing and the daily average production being obtained by the various producing methods used in the Bolivar coastal fields at the end of 1933.

TABLE 5.—*Distribution of Production According to Production Methods at the End of* 1933, *Bolivar Coastal Fields*

Production Method	No. of Wells	Daily Average Production, Bbl.	Percentage of Total Production	Average Production per Well per Day, Bbl.
Flowing	369	121,471	48.20	329
Gas-lift	179	73,455	29.14	410
Pumping	292	57,114	22.66	196
Total	840	252,040	100.00	300

The number of gas-lift wells decreased by 45 as compared to the end of 1932 due mainly to the decline in high-pressure gas production. There was an increase of 99 pumping wells due primarily to the initiation of pumping on a large scale in the Lagunillas field, where, at the end of 1933 there were 83 pumping wells producing compared to only 7 at the end of 1932.

The advance of the edge water in the southern part of the Lagunillas field has been partly controlled by continuous repair work in wet wells, but the percentage of water in the oil production is steadily increasing, and treating of wet oil, which has been in the experimental stage for the past two years, will become necessary on a much larger scale in the future.

Mene Grande Field (District of Sucre, State of Zulia).—Production from this field during 1933 showed a decline of approximately 4 per cent under the 1932 figure; however, at the end of the year the daily average production of 39,110 bbl. was 3,600 bbl. higher than at the end of 1932. Drilling was resumed in October with two drilling strings and two wells were completed by the end of the year.

Concepcion and La Paz Fields (District of Maracaibo, State of Zulia).—Drilling was resumed in the Concepcion field during the early part of the year but was again discontinued in September, after the completion of only two wells, both of which were producers. Production was maintained at approximately the same level as in 1932, yet at the end of 1933 the daily average production of the field at 6,120 bbl. was 7 per cent higher

than at the same time in 1932. This increase is due entirely to the production being obtained from the two new wells. No new drilling was done in La Paz field and production showed a decrease of approximately 33 per cent under the 1932 figure, while the daily average at the end of 1933 at 685 bbl. was 25 per cent less than at the end of 1932.

Rio Tarra and Los Manueles Fields (District of Colon, State of Zulia).—Two new wells were drilled in the Rio Tarra field during 1933, but at the end of the year these wells were reported as testing and it is probable that they will be deepened before they are considered as final completions. Production remained at approximately the same level as during 1932; however, at the end of the year the daily average production was 25 per cent higher than at the end of 1932. Three new wells were completed in Los Manueles field during the year. Although the 1933 production for the field showed an increase of 40 per cent over that of 1932, the daily average at the end of the year was 25 per cent lower than at the end of 1932.

Other Fields.—No additional drilling was done in the Netick field located in the District of Mara, State of Zulia, and the two producing wells of the field remained closed in during the year. This field has a potential production of 500 bbl. of 24° Bé. daily. The Totumo field, in the District of Perija, State of Zulia, with a potential production of 2300 bbl. daily, likewise remained closed in throughout the year.

Wildcats.—There were no wildcat test wells drilled in the Maracaibo Lake Basin during 1933.

Field Developments, State of Falcon

El Mene Field (District of Buchivacoa, State of Falcon).—No additional drilling was done in this field during 1933 and production showed a further decline of 25 per cent under that of 1932. Production continues to be almost entirely dependent on artificial methods.

Media Field (District of Buchivacoa, State of Falcon).—Exploratory drilling was carried out in this field during the entire year, but results were very disappointing. Out of 11 wells drilled, only three were completed as producers and one as a high-pressure gas well. Production for 1933 showed an increase of 20 per cent over that for 1932, but at the end of 1933 the daily average production of 1050 bbl. was 55 per cent less than at the end of 1932. Gas repressuring was tried out in this field during the early part of the year but was abandoned, inasmuch as it was found that it served only to increase the gas-oil ratio and had no effect in increasing the production nor in slackening the very high rate of decline.

Cumarebo Field (District of Zamora, State of Falcon).—Development in this field continued during 1933 and 16 new producing wells were completed for an average initial production of 1050 bbl. Five drilling

strings were in operation during the early part of the year, but in December only two were active, one of which was engaged in drilling a deep test in the central portion of the field. Production for the year amounted to 4,982,000 bbl. as compared to 2,055,000 bbl. produced during 1932; however, active exploitation in this field was not undertaken until the middle of 1932 and therefore the figure for that year does not represent a complete year's production. The daily average rate of 14,390 bbl. at the end of 1933 representing approximately 85 per cent of the field's present capacity was slightly less than the daily average recorded during December, 1932. A compressor station was completed at Cumarebo in March, 1933, and since that time gas repressuring has been carried out continuously, and at the end of the year four wells were being used for the introduction of gas into the formation.

El Mene de Acosta Field (District of Acosta, State of Falcon).—Drilling was suspended in this field in April, 1933. Only two wells were completed during the year, one of which was a small producer. Production showed a further decline of approximately 20 per cent under the 1932 figure.

Other Fields.—The Urumaco field with a potential production of 2000 bbl. daily, situated in the District of Democracia, State of Falcon, and Las Palmas field, with a potential production of 900 bbl. daily, situated in the District of Buchivacoa, State of Falcon, remained closed in during the entire year.

Wildcats.—The Standard Oil Co. of Venezuela completed the only two wildcats drilled in the State of Falcon during 1933. La Vela No. 3, in the District of Colina, was abandoned as a dry hole at a depth of 4705 ft. and Ricoa No. 1, in the District of Zamora, was likewise abandoned as a dry hole at a depth of 6404 ft. The same company deepened its La Vela No. 2 from 2822 to 3320 ft. but again it resulted in a high-pressure gas well, with no oil. At the end of the year, the British Controlled Oilfields Ltd. was rigging up its La Guinea No. 1 wildcat in the District of Buchivacoa.

Field Developments, Eastern Venfzuela

Quiriquire Field (District of Piar, State of Monagas).—Drilling was suspended in this field in April, 1933, but was again resumed in August, and nine producing wells were completed by the end of the year. The production for the year, which amounted to 6,698,000 bbl., was the highest for any year in the history of the field and was 35 per cent higher than that of 1932. The daily average production at end of the year was 22,820 bbl. as compared to 10,867 bbl. at the end of 1932. Very satisfactory results are reported from gas repressuring, which was started in this field in February, 1933, and several wells which formerly were considered as candidates for artificial lift have returned to natural flow status.

A new export terminal for the loading of ocean tankers is being constructed by the Standard Oil Co. of Venezuela, at Guiria, on the southern coast of the Paria Peninsula in the District of Marino, State of Sucre. Oil will be transported, by shallow draft tankers to Guiria from Caripito, the present loading terminal for the Quiriquire field on the San Juan River.

Guanoco Field (District of Benitez, State of Sucre).—This field remained closed in during the year.

Wildcats.—The most important new oil strike of the year was that encountered in Pedernales No. 2, the third test well to be drilled by the Standard Oil Co. of Venezuela in the Pedernales area of the Territory of Delta Amacuro. This well blew out in April, 1933, at a depth of 1571 ft. with an estimated flow of 5000 bbl. daily of 17.8° Bé. oil. However, although the blowout was speedily controlled, considerable difficulty has been experienced in efforts made to complete the well as a commercial producer, owing to the very silty nature of the producing horizon, which causes the well to sand up after flowing for only a short period. In September, with 60-mesh screen liner installed, the well averaged only slightly more than 200 bbl. daily through a 7/16-in. choke during the few days it produced before it again sanded up. Up to the end of the year, no commercial production had been reported from the well. A fourth well, Pedernales No. 3, approximately 110 meters northeast of Pedernales No. 2, was being prepared for a test at a depth of 3034 ft. at the end of the year.

A small amount of oil was also encountered by the Standard Oil Co. of Venezuela in two wells drilled in the Orocual area in the District of Piar, State of Monagas, about 20 km. southwest of the Quiriquire field. Orocual 2, which was drilled to 5021 ft., was plugged back to 3183 ft. and completed at that depth as a very small pumping well. Orocual 3 was completed at a depth of 3016 ft. as a 150-bbl. pumper. The oil from both wells is very heavy and the gravity was reported as being between 12° and 13.5° Bé. Additional exploration is expected to be carried out in this area during 1934.

At the close of the year, La Pica No. 1, in the District of Maturin, State of Monagas, on pooled acreage of the Compania Espanola de Petroleos, the Lago Petroleum Corporation, and the Standard Oil Co. of Venezuela, and drilled by the last named company, was fishing for lost drill pipe at a depth of 5857 ft. Dry gas was encountered at 5040 ft. but no oil shows were reported. It is understood that the well is scheduled for abandonment.

During the year the Venezuela Gulf Oil Co. drilled Oficina No. 1 to 6184 ft. before moving off the tools to its No. 2 location. This well made only dry gas but in considerable volume. The Oficina area is in the District of Freites, State of Anzoategui, about 130 km. northwest of

Ciudad Bolivar. The same company is preparing to drill additional wells in both the northern and southern parts of Freites.

The increasing tax burdens on the large holdings of the various companies in Eastern Venezuela will probably necessitate further test drilling during 1934, in order to eliminate acreage of least promise. At the present time several companies are busily engaged in carrying out geological and geophysical exploration work. Various engineering parties have been active during 1933 in surveying concessions on which maps are due to be presented to the Government in 1934.

Chapter V. Refining

Developments in Refinery Engineering during 1933

By Walter Miller,* Ponca City, Okla.

(New York Meeting, February, 1934)

Advancement in engineering in the refining industry during 1933 might be likened to the jagged flame of a poor wick-test kerosene—a few outstanding high spots, but not broadly spectacular.

Economic conditions were unsatisfactory for the first six or eight months, but the improvement in the latter part of the year had some immediate effect in stimulating new designing and building. The national legislative program involving the industry drew the attention of executives away from petroleum technology to some extent. The National Recovery Act, and its offspring, the Petroleum Code, demanded deep and continued study to put the machinery into smooth motion. From a purely technical engineering stand, therefore, the emergency measures might be considered a temporary brake on progress. The ultimate effect, if the whole industry can get back "out of the red," may well be a more than expected advance. Of course, petroleum technologists and engineers, including both those engaged within and those busy in designing and building for the industry, continued their efforts, and much of the results of their work will undoubtedly see the light of day under the improved economic conditions, which bid fair to stay with us. There was little improvement during 1933 in atmospheric distillation, sweetening processes, or furnace design, but experimentation during the year on these subjects may materialize into distinct advances.

The trend toward compact distilling and fractionating equipment, especially in the Appalachian district, deserves noting. A number of refineries in that district replaced obsolete shell still units with up-to-date tube stills and efficient fractionating towers, both for the better separation of lubricating fractions from the crude and for improving the boiling range of the gasoline. A number of small skimming and topping plants in flush fields, such as East Texas, which felt the pinch of production control, were forced to shut down, but the stronger among them are consolidating their positions by installing cracking equipment and in some cases more modern crude-distillation units.

Motor Fuel

For the first time in many years a reviewer is able to point to at least a temporary cessation in the competitive race in the manufacturing

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and marketing of gasoline with higher anti-knock value. The A.S.T.M. rating of 70 octane is generally accepted as a maximum figure for the broadly marketed brands. Nonpremium products of higher octane value are few and far between. It is unfortunate that a movement initiated during the year to set the top figure at 65 or 67 failed of accomplishment. There is certainly much in favor of the idea that 65 octane would have been sufficiently high for satisfactory road performance in most of the cars in use. There are some grounds for basing the general hope that the top in this race has been reached.

The rapid trend toward "re-forming," so evident in 1932, was rather effectually slowed up by tetraethyl lead becoming available for non-premium gasoline. Limiting the use of ethyl lead to gasoline with a maximum of 70 A.S.T.M. to prevent undue competition with premium gasolines helped also to establish, at least temporarily, a "ceiling" of 70 in the octane race. Considerable re-forming is still being done but installation of specialized units for the purpose has practically ceased. As gasoline prices rise it becomes more difficult to justify the reforming operation as against the use of ethyl lead for octane raising, by those to whom it is available.

The advantage of re-forming for volatility improvement stays more constant because the cost of casinghead gasoline to the refiner has advanced somewhat in line with improved motor fuel prices. The question of whether to suffer the extra cost of practicing re-forming to improve volatility or to use natural casinghead gasoline depends largely upon local conditions and the "spread" between prices of motor fuel and natural gasoline.

Motor designers and manufacturers have made improvements, which, in many instances, have lessened the knocking problem and in some cases removed the bugbear almost entirely. Automatic spark control and the use of aluminum alloys for cylinder blocks, cylinder heads, and pistons, are to a considerable extent credited with this improvement.

The adoption as a tentative A.S.T.M. standard by the American Society for Testing Materials early in the year of the improved anti-knock test equipment developed by the Cooperative Fuel Research Committee has brought about improved conditions in anti-knock evaluation and comparison of motor fuels. Some additional refinement of the method, and additional correlation with automotive performance, is still looked for but it is in the main much better than any method previously generally available.

Another "top" in gasoline quality is rapidly being reached. The trend toward greater average volatility noted during 1932 continued through 1933 to almost its ultimate logical limit. The effect of this increased demand upon the casinghead or natural gasoline industry has been gratifying indeed to those engaged in it, since the average price

for natural gasoline during the last half of 1933 was more than double that of the previous year and a half.

The threat by the "agricultural" interests to force the inclusion of alcohol in motor fuel caused much discussion and made necessary extensive testing programs leading to full knowledge of the factors controlling the use of blended fuels. The proposals were proved to be unsound from many standpoints and patently inadvisable after careful study of their influence upon all concerned. They were denounced by some as an attempt at economic class legislation in favor of agriculturists at the expense of the petroleum industry and the public generally.

The proposals will undoubtedly be brought out again in the legislative halls during 1934, but the large amount of technical study given the problem by unbiased investigators during 1933 should strengthen the opposition materially.

The trend in refinery cracking methods has followed advisable changes in gasoline specifications and improvements in mechanical construction and materials. The influence on re-forming (cracking) of low octane gasolines and naphthas has already been noted. By increasing use of alloyed steels and improved methods of fabrication of cracking plant equipment, plants now can be built that will better withstand the extreme conditions of temperature, pressure and corrosion to which the metals are exposed. The use of alloyed steels in exchangers, welded vessels, valves and fittings has been further developed for high-temperature and pressure use. The trend is definitely away from the former high-pressure soaking drums and reaction chambers toward the accomplishing of the same objects by more scientific design of tube banks and better temperature condition control. Recently developed units provide for separating the cracking stock into a number of fractions, which are subjected to the particular cracking conditions most suitable for each individual fraction. Some of the still units erected provided for as many as three or four separate sets of heating tubes, each located in a zone of heating especially adapted to the character of the charging stock fraction and the end product desired. Noteworthy are developments in "viscosity-breaking" in which the normally viscous reduced crude undergoes a carefully selected temperature and pressure treatment in which additional gas oil for conversion into gasoline is obtained, and the resulting fuel oil is molecularly rearranged to yield an industrial fuel possessing the desirable properties of fluidity and freedom from excessive tar and coke content. The trend of the refinery away from a mere separating plant and toward a true organic chemical plant grows rapidly.

Lubricants

Refining lubricating oils by solvent extraction has been the dominating point of interest in manufacture of lubricating oil during the

year. The subject occupied a most prominent place in the technical refinery meetings. Many compounds, varying widely in characteristics, have been tested for their solvent powers, and a total of eight or nine processes are now available for the refiner's choice. Several commercial plants are in course of construction and a number of organizations have projects for installation under active consideration. Others, with the thought that the high viscosity index, low carbon residue, and oxidation characteristics of solvent-treated lubricants constitute a quality of lubricating oil really not needed except for highly specialized purposes, are watching the situation in the hope that it will be unnecessary to make the investment and incur the extra operating cost, but distinctly fearful of the possibility that competition will force them to take the step willy-nilly. Inasmuch as the quantity of solvent-extracted lubricants offered to the public will be greatly increased during 1934, accompanied by a considerable fanfare of advertising, the absolute necessity for installation should be pretty well cleared up during the current year. It will be a most interesting development to watch.

The use of self-induced refrigeration for dewaxing various lubricating-oil stocks has been developed and described by the Standard Oil Company of Indiana and others, and should obtain rather widespread study as need for modernization of present refrigerating equipment arises. At least two volatile solvents have been proved satisfactory in commercial use, and the simplicity of the process will probably affect the economies of operation of the old type of dewaxing methods now in use by nearly all refineries manufacturing lubricating oil. Some refrigerants may be developed having refining action in addition, which would probably make their commercial application more desirable and more easily justified from an economic standpoint in problems involving replacement of existing older style plants.

Deasphalting lubricating stocks by the use of solvents was given further impetus and doubtless will become an important development both to the refiner and, in a negative way, to the acid manufacturer. The deasphalting of lubricating oil by solvents naturally will reduce the required acid treatment, and probably will conserve a considerable part of the loss of valuable constituents of lubricating oil encountered with heavy sulfuric acid treating.

Extreme-pressure lubrication and extreme-pressure lubricants have doubtless been among the most vital problems of the refiners and automotive engineers. The increasing pressure on bearing surfaces required by the design of new mechanical equipment calls for lubricating oil and greases with much higher film strength. The very best quality of straight petroleum lubricants will break down and allow metal-to-metal contact at loads that the automotive engineer desires to utilize in improving motor-driven equipment. The general solution of the problem of

extreme-pressure lubricants was rendered more complicated by the lack of testing equipment or devices that would give concordant results. Gratifying strides have been made during 1933 and more satisfactory testing machines and methods undoubtedly will be brought out in 1934. The final solution of the problem will require the production of lubricants with extreme-pressure characteristics that are not objectionable from other standpoints. Many of the extreme-pressure lubricants now on the market are unsatisfactory because of an excessive tendency toward corrosion and general instability in so far as oxidation, sludging, color and odor are concerned.

While the solvent processes for lubricant manufacture foreshadow reduced sulfuric acid treatment, great quantities of acid continue to be used. The attendant sludge-disposal problem has been troublesome. Methods for successfully and efficiently burning have been in use to a limited extent for some years, but are not applicable economically in all cases. A process of disposal brought to successful application during the year enables the refiner to convert his acid sludge into high-quality acid and marketable coke. There is some hope that the unsightly sludge ponds will in time become a memory.

Fuel Utilization

The refining industry in 1933 turned further toward a utilization of waste products from its own operation, rather than to the outside sources of supply. The U. S. Bureau of Mines Survey of Refinery Fuel Consumption for 1932 showed that the primary refinery fuel was residue gas (stripped of any liquefiable gasoline content) while the consumption of acid sludge increased markedly.

The improved economic conditions indicated and hoped for during 1934 will, it is thought, give stimulus to refinery engineering progress lacking during the last few years.

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